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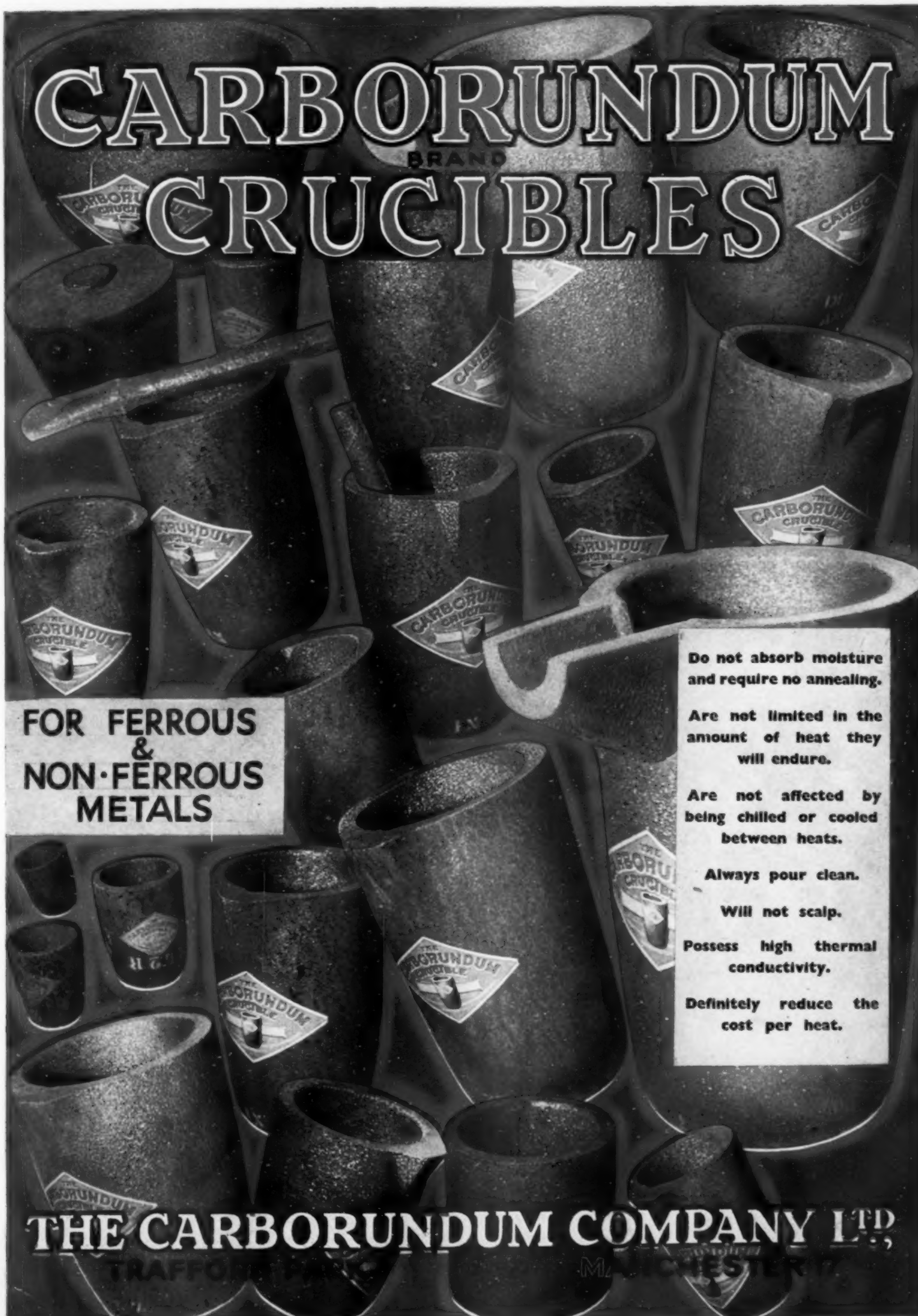
METALLURGIA

THE BRITISH JOURNAL OF METALS



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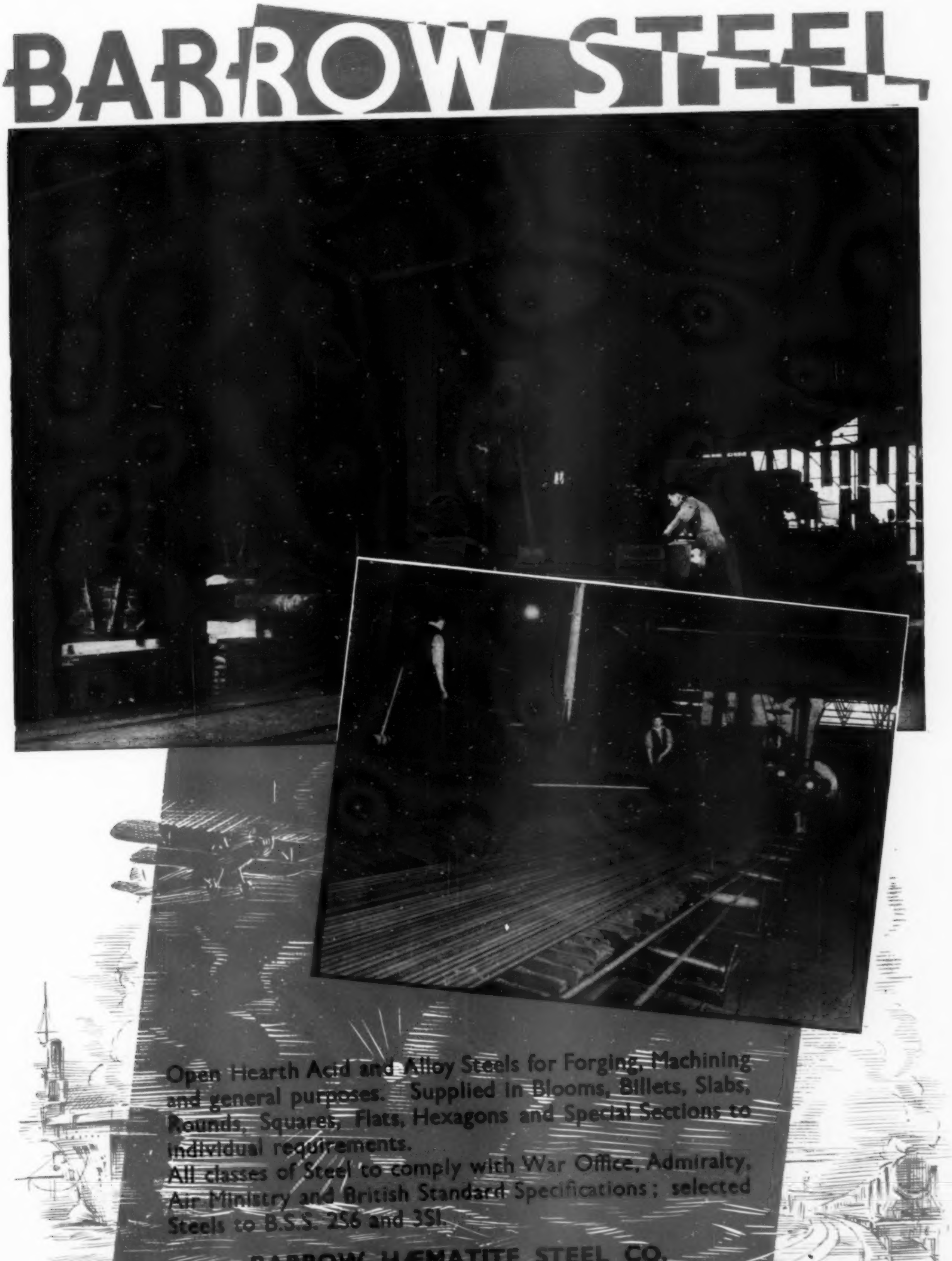
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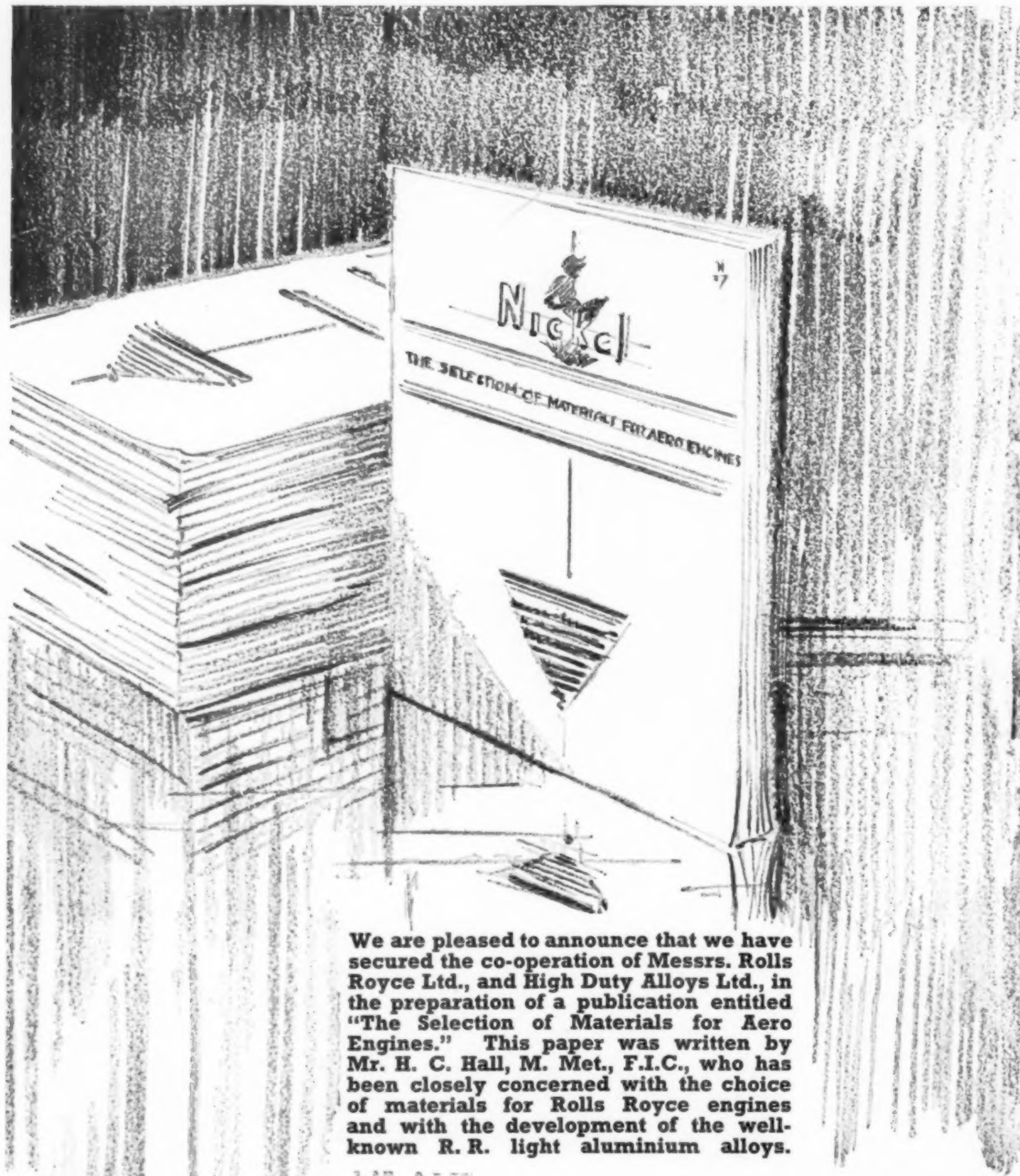
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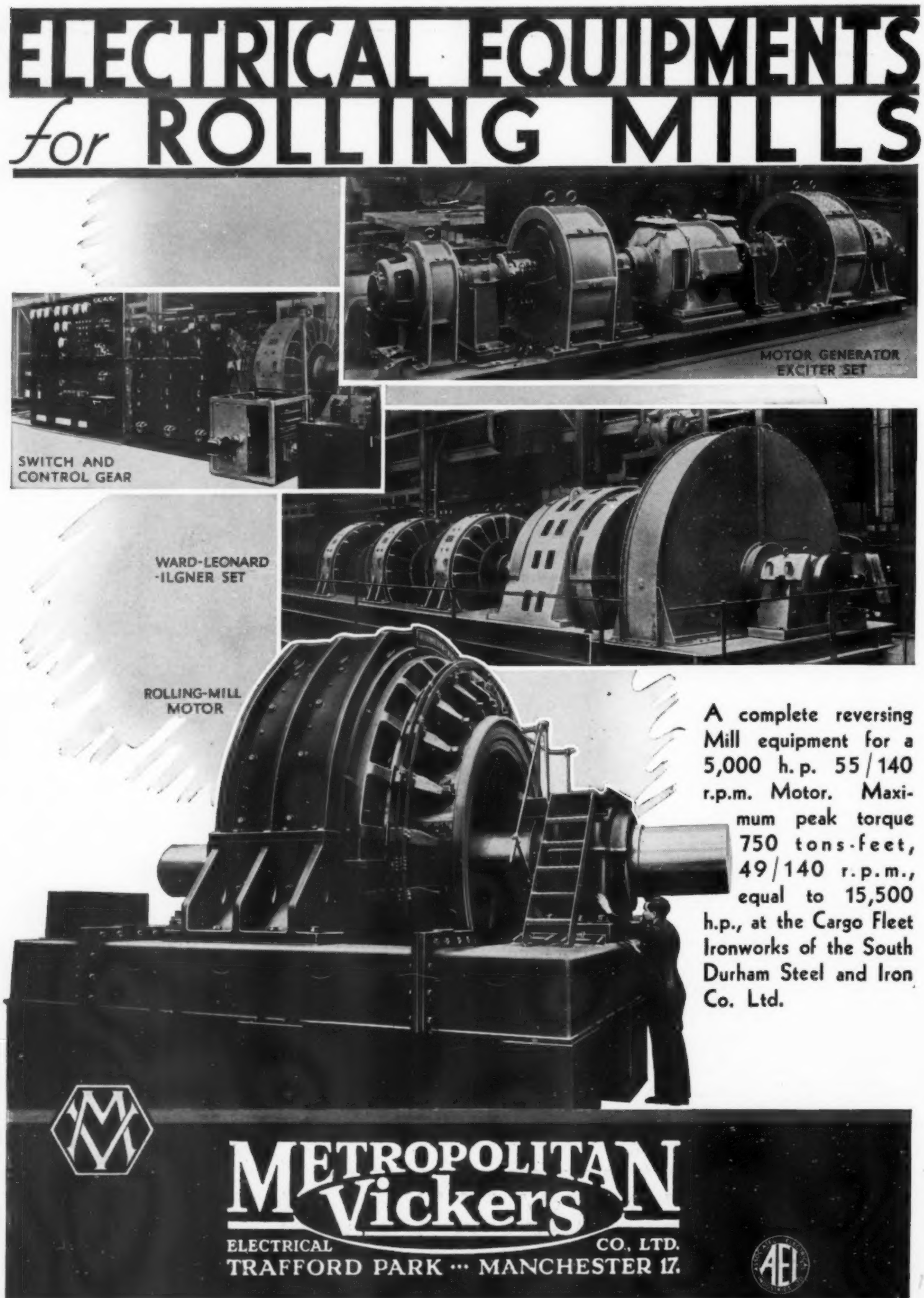
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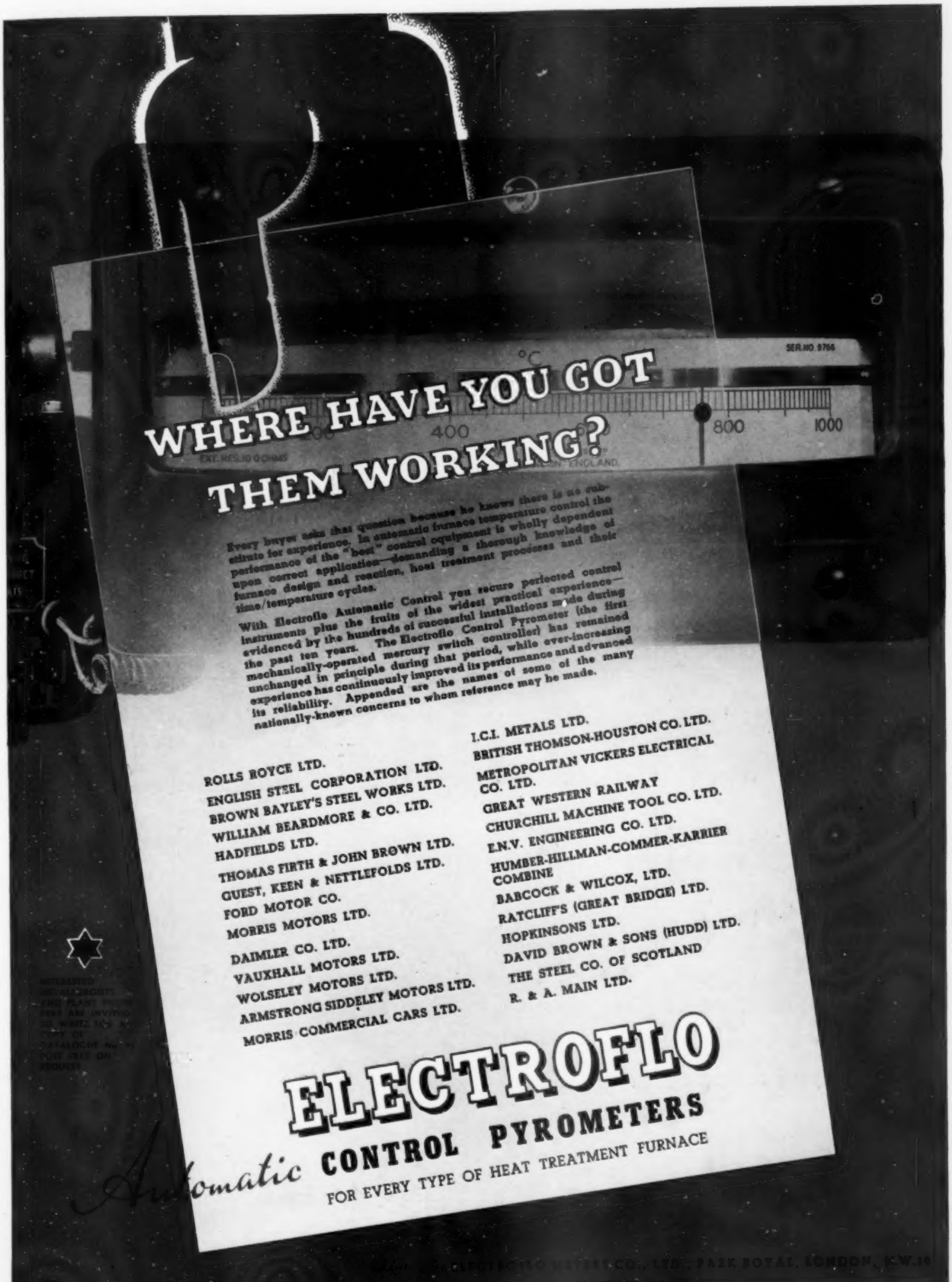

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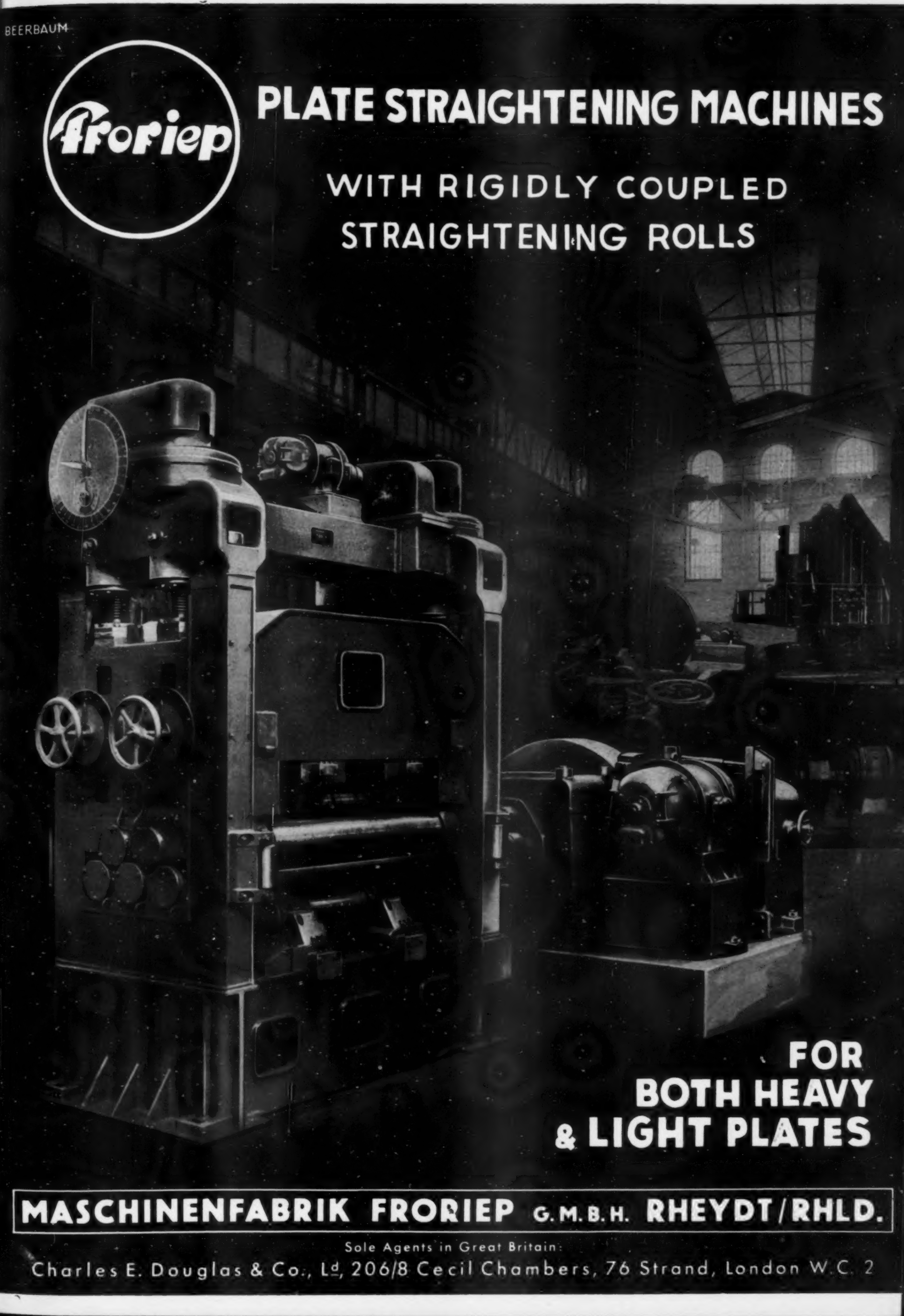
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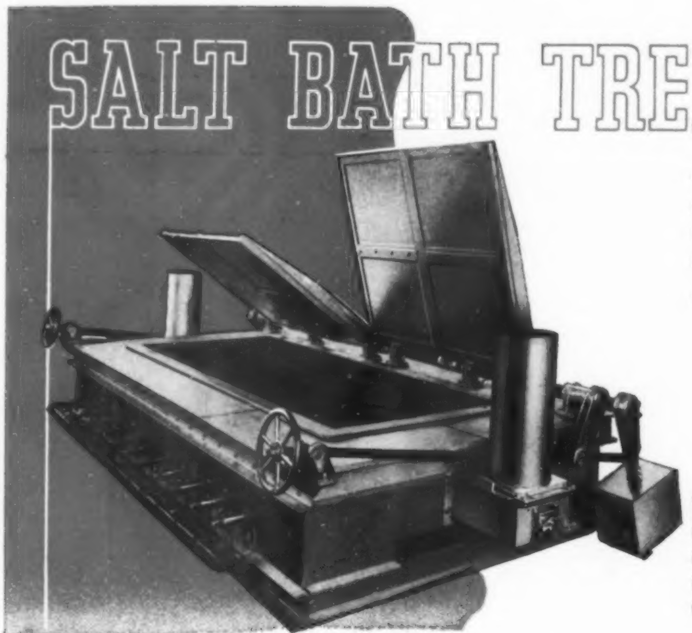

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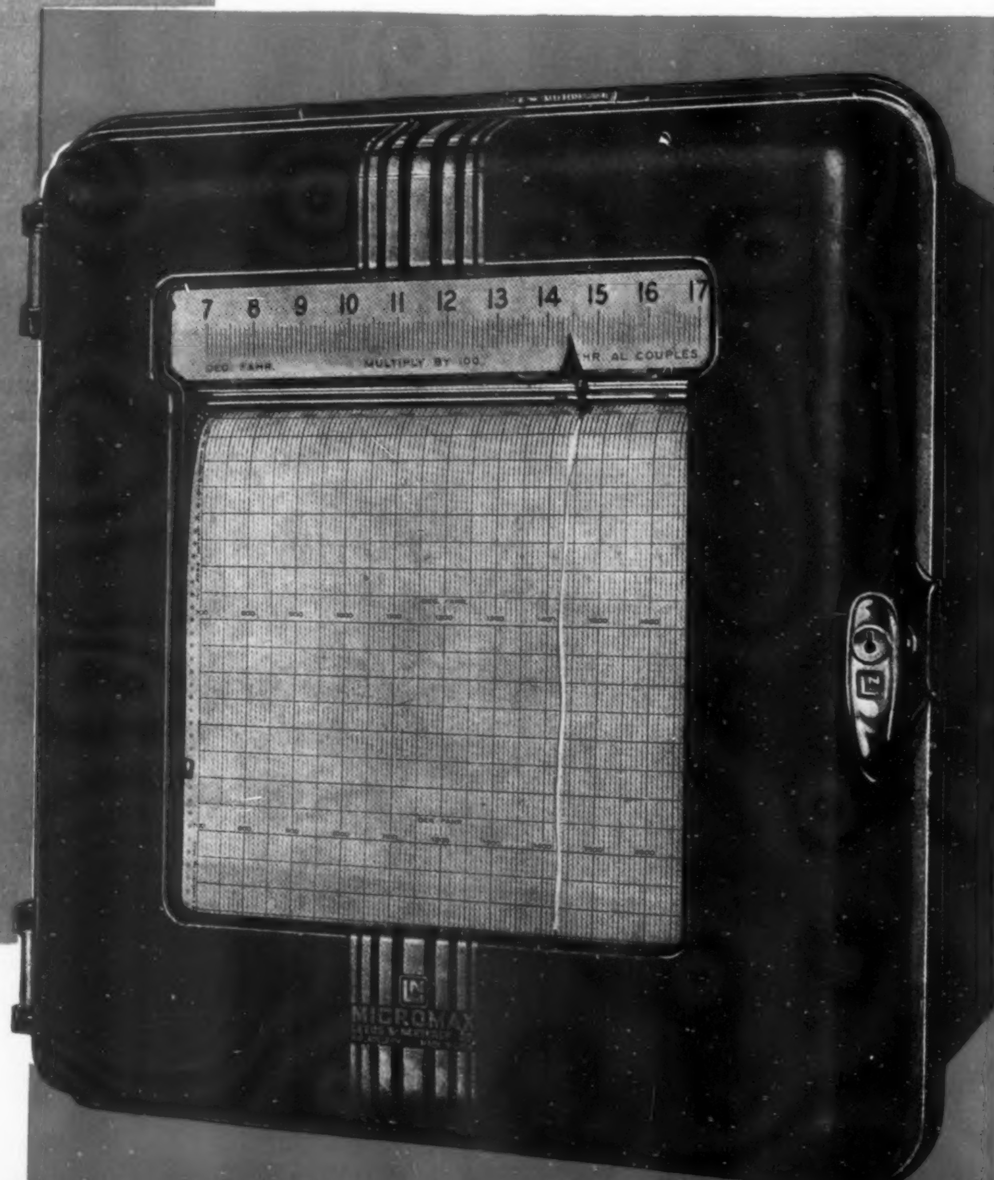

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METALLURGIA

The British Journal of Metals
(INCORPORATING THE METALLURGICAL ENGINEER.)

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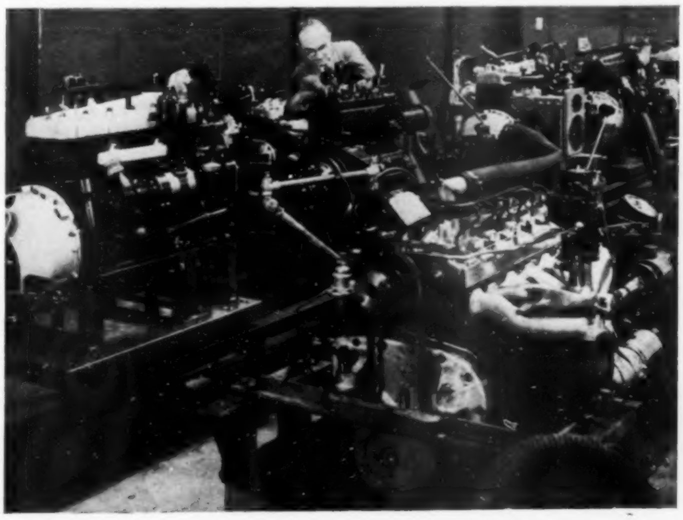
MOTOR-CAR PRODUCTION

AT THE COVENTRY WORKS OF THE HUMBER-HILLMAN CO.

Improved design and materials, the skilful use of new and improved machines, and the correct assembly of thousands of individual parts are all contributory factors in the construction of a car, and mean much in its performance, but only a "behind the scene" investigation shows how much. Following a recent visit to the Humber-Hillman Works, the manufacturing procedure is reviewed.

DEVELOPMENT in every section of the industry — design, materials, manufacturing equipment and technique, and procedure—has contributed in providing what can be termed the modern trouble-free car. Each year sees some new features or refinements together with constantly developing manufacturing technique, improving the standard of service the motorist enjoys. Manufacturers have increasingly made use of the developments in metallurgy, and some, including Humber and Hillman definitely define the materials of which various parts are composed. This trend seems to indicate that, in addition to becoming mechanically-minded, the discerning motorist may also become metal-minded, and be able to discus the relative advantages of this or that metal or alloy for the various components of a car.



A corner of the engine-test department where all units are run-in, tested and tuned before finally passing a stethoscope test.

There is much truth in the statement that no industry has given greater attention to the application of metallurgical developments than the automobile industry, and in this respect the Humber-Hillman concern is no exception. The variety of ferrous and non-ferrous metals and alloys used in this group's products is very considerable and applies equally to the volume production of the 10 h.p. Hillman Minx, as to the larger and more individually-produced Humber cars. On the ferrous side carbon steels continue to be used for constructional purposes and many engine components; there has been little change in this type of steel, except in improved quality of greater reliability. The carbon steels used range from the low-carbon bright steel sheet to a heat-treated 0·40% carbon steel, and include free-cutting steel and a 0·30% carbon steel in both normalised and heat-treated conditions. High-carbon steel is used also, but to a more limited extent, for such purposes as high-tensile wire for valve springs.

For key parts, which require stronger material or greater resistance to wear, the use of low-alloy and high-tensile alloy steels is increasing, the former including the nickel steels, manganese, molybdenum steels and chromium-molybdenum steels; the latter the nickel- chromium and the nickel-chromium-molybdenum types of alloy steels. Case-hardening alloy steels, because of their higher core-strength and toughness combined with good wearing properties are used for many engine details in preference to case-hardened carbon steels.

Probably the most important change in automobileengineering in recent years is the use of light alloys. In addition to reliability and endurance of the components, the desire to reduce weight per horse-power has resulted in the adoption of many light alloys as standard practice for many parts. In the Humber-Hillman products both aluminium-silicon and aluminium-copper alloys are used for various engine components while an aluminium-copper-zinc alloy is also used. Other non-ferrous alloys used include a number of zinc-base alloys for various fitments and various bronzes for bearings.

Checking Consignments of Material

It is obviously necessary to ensure that these materials meet specifications, and the steps taken to check consignments of the various materials and semi-finished products have an important bearing on the ultimate service life of the cars of which they form a part. Well-equipped physical and chemical laboratories, adequately staffed, ensure the maintenance of a high standard. With bar material and stampings, for instance, a sample is taken from each consignment and submitted to chemical analysis. The physical properties are checked after the standard heat-treatment or normalising treatment specified. Bolts and studs from each consignment are submitted for hardness, fracture and chemical tests. Chemical analysis, tensile, transverse and hardness tests are taken daily on the cylinder and "general" irons used in the foundry,

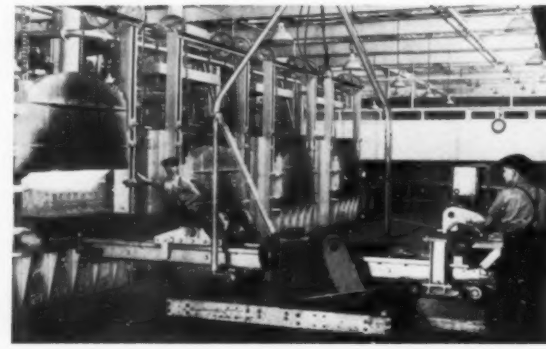
The apparatus designed and capable of testing every electrical component used in modern motor-car manufacture.

while periodical chemical analysis and physical tests are carried out on aluminium-alloy pistons, and all incoming non-ferrous alloys.

Heat-treatment

To obtain the best properties from the materials used under modern heat-treatment plant and equipment is an outstanding feature at these works. Various furnaces are located on the line principle on which the factory is planned, so limiting the movement of parts to be treated. Electric and gas furnaces are used ; these include four Gibbons natural-draught gas-fired carburising furnaces, each of which is provided with its own control pyrometer which adjusts a main gas-control valve and the stack damper through a valve regulator. Each control pyrometer is provided with a thermo-couple safety device which protects the furnace and its contents from damage due to excessive temperatures in the event of the failure of the thermo-couple or its circuit. In addition, the temperature of each furnace is recorded on a four-point temperature recorder. There are five gas-fired cyanide baths and one electric, each fitted with automatic temperature-control equipment. One of these gas-fired baths and its corresponding control pyrometer are shown in an accompanying illustration, in which the valve regulator, actuated by the control pyrometer, adjusts the main gas- and air-valves.

There are a large number of electric furnaces installed by Birmingham Electric Furnaces Ltd., all of which are provided with Electroflo control pyrometers. There are two special 220-k.w. three-zone continuous pusher-type furnaces, one of which is used for hardening or normalising forgings, and the other for normalising or tempering forgings. The other furnaces include a 45-kw. special rotary hearth, continuous furnace for reheating crown wheels ; two 40-kw. forced-air circulation furnaces for tempering gears ; a 70-kw. special continuous pusher-type furnace, with automatic discharge mechanism for hardening camshafts ; a 10-kw. carburising furnace ; and several special furnaces installed for the treatment of high-speed-steel and carbon-steel tools. In several instances there is a positive control of the furnace atmosphere, so that every effort is made to abolish risks and uncertainties in the heat-treatment of even the most delicate cutting tools and other difficult components.



A battery of gas-fired, heat-treatment furnaces with an electric loader for charging and discharging.

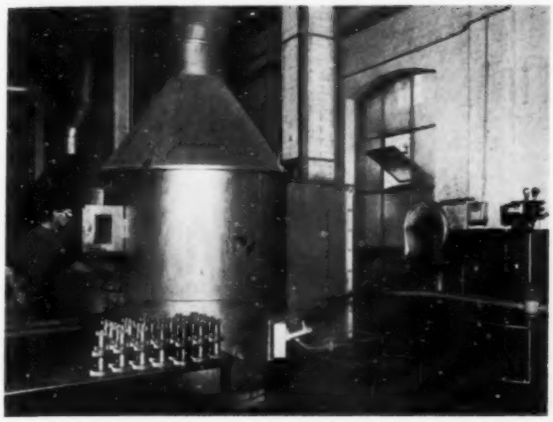
Die-casting Shop

Practically all the metal fitments in the various cars produced by this organisation are die-cast. For this purpose the die-casting shop is equipped with pot feeding Madison-Kipp and Buhler die-casting machines in which the temperature of the metal is controlled by Electroflo control pyrometers operating on motorised control gas valves. It is noteworthy that this firm appreciates the outstanding properties of zinc-base alloys and the advantages they offer for modern high-production requirements. The artistically-designed body fitments so familiar to the motorist are produced from zinc-base alloys which, by means of die-casting methods, produce the many intricate designs with great accuracy and high-quality finish.

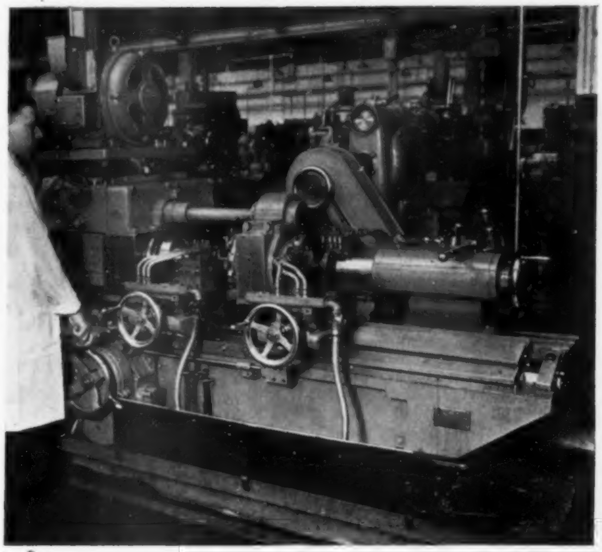
Iron Foundry

The " blackheart " and " whiteheart " malleable iron castings used are obtained from outside sources, but the large proportion of the remaining iron castings are produced in the foundry which forms a part of the factory. For general work iron of a suitable composition is melted by cupola, but alloy cast irons, such as for nickel-chromium iron castings are melted in Birlec-" Lectromelt " direct-arc furnaces. Two of these furnaces are installed, each with a rating of 600 kv.A. and a maximum melting capacity of 1,200 lb. per hour each. These furnaces provide facilities for the rapid production of metal with closely-controlled analysis and exceptionally good physical properties, the product being of consistently uniform quality.

The engine assembly line.



One of the gas-fired cyanide baths fitted with Electroflo automatic temperature-control equipment.



One of the latest independent, semi-automatic lathes for forming front and rear of crankshaft.

Machine Shops

While the quality and character of the material put into a car has much to do with the subsequent service many manufacturing processes must be carried out with that degree of precision which will ensure accuracy of assembly and the best conditions for that service. At these works the keynote is planned economy of production with unusual precision of machining. In the extensive machine-shops all work is arranged for sequence of flow. Machines are arranged in parallel lines ; the stamping, forging, casting or other part passes from machine to machine for subsequent operations, and is checked at the end of the sequence by inspectors armed with special gauges.

Many of the machines are automatic, some mechanically and others electrically controlled, some doing a multitude of operations simultaneously, as in the case of camshafts, where the bearings and spaces between the cams are all turned at the same time ; or differential housings which are bored out, the faces turned and the four lugs milled off in the same period of time ; or axle shafts which have their many machined faces turned simultaneously.

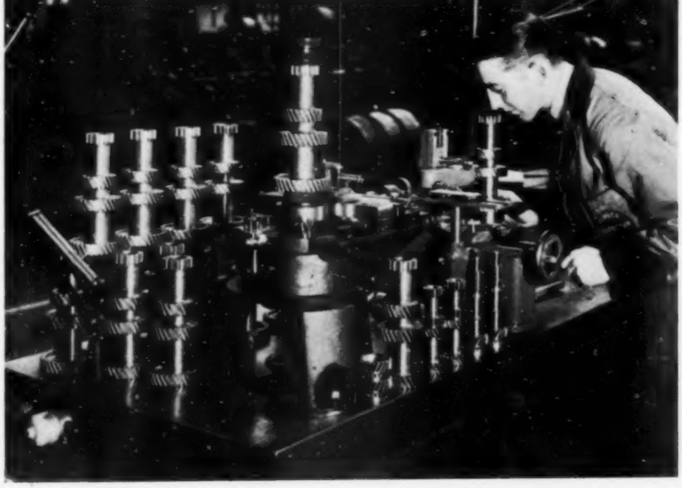
Fine boring is extensively used in the machine-shops, and this extreme precision results in a saving of time in assembly, better fitting, longer life and smoothness of use. Parts which are fine bored include cylinder blocks, piston gudgeon-pin bores, connecting-rod bearings, piston bores in cylinder block, and main-bearings. Accuracy of main bearing fitting is well shown by the fact that the crankshaft can be turned easily by hand after the main bearings have been tightened fully and inserted. The cylinder bores are honed after fine-boring, resulting in a mirror finish, and in these bores work aluminium pistons of the T-slot, semi-split-skirt type, the skirts of which are diamond turned for excellence of bearing surface, and consequent reduction of friction, in addition to accuracy of fit.

The truth and finish of cylinder bores and connecting-rod bearings are checked by Solex plug gauges which can measure quite easily to a limit of 0·0001 in. Cylinder bores must be accurate within very fine limits of size, squareness, parallelism and ovality, and with this gauge, the scale of which is graduated in magnifications of 0·0001 in., any deviation from accuracy is at once detected.

One of the most up-to-date sections is that devoted to gear cutting. Automatic machines complete a sequence of operations ; one hobbing machine takes four clusters of gears at once, the first machine of its type to be installed in this country. One of the final operations, through which all gears pass, is a finishing machine where the gear-wheel passes over a rack which shaves up the teeth where required, correcting the tooth-form and spacing, and any other inaccuracy.

Grinding and broaching are widely used in this factory where extreme accuracy of all components is insisted upon. Connecting-rods are broached and the bore ground out ; valve seatings are ground—the exhaust-valve seats are of hardened-steel inserts—instead of being cut, using an accurately ground pilot mandrel through the valve guides for truth of location. A new machine has been installed for broaching the faces of gearboxes to replace the previous milling process.

One of the many inspection benches on which every set of gears is individually scrutinised, measured and tested prior to assembly.

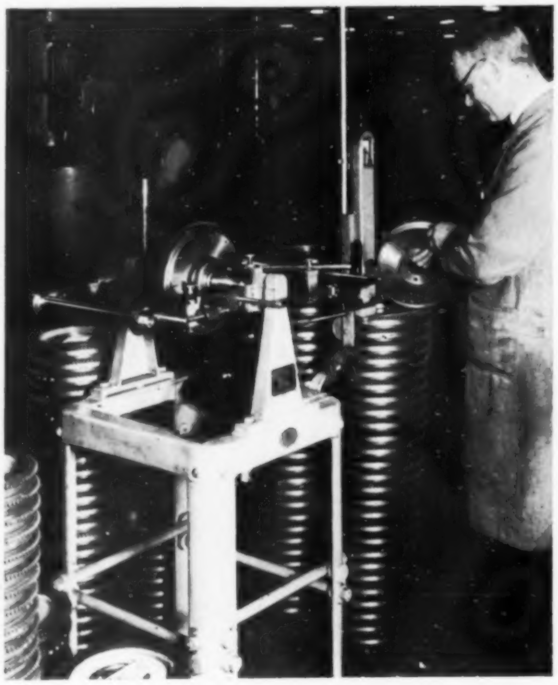


Assembling

As an indication of foresight in manufacturing technique it is of interest to refer to the completion of the connecting-rod bearings. All Hillman engines have steel-backed, white-metal-lined bearings ; those of the larger models are centrifugally cast, or spun, into the metal of the rod. By this process a comparatively thin covering of white metal becomes an integral part of the rod, and, in the rare event of a run-out bearing (through shortage of oil, for instance), little or no harm would result to the engine if driven with reasonable care to the nearest garage.

Care in manufacture is shown by the methods employed in the balancing of fan and pulley assemblies, balancing of completed flywheels, and

Testing the ovality of gudgeon-pins after grinding.



The apparatus employed to statically balance every flywheel to precision limits. It is a standard production operation for the Hillman Minx.

the precautions taken to balance and match up connecting-rods, pistons and gudgeon pins, whilst the crankshaft is balanced both statically and dynamically to extremely fine limits. Connecting-rods are weighed and selected to come within limits of two drams, and the pistons are also selected within the same weight limits. This ensures engine balance and operating smoothness, as well as longer life through absence of vibration and uneven running.

The chassis frames are of the box-section type, and in this connection a demonstration unit staged in the factory showrooms is very intriguing ; it demonstrates the superiority in rigidity of the box-section type of structure in comparison with the ordinary cross-braced frame type. Two scale models, one of each type are placed side by side and connected to spring balances which show the comparative amount of force required to distort these frames through the same degree of movement. In this test the box-section frame needed more than seven times the force applied to the braced section to distort it to the same degree.

Well-planned flow is also apparent in the assembly sections. The chassis frames travel along slowly-moving conveyer tracks, receiving front and rear axles, springs, engine and gearbox units ; the body, already trimmed and fitted with necessary parts, meets the chassis, steering column and other connections are made. The car grows gradually, with inspection at each stage. The various components are fed to the main assembly line from sub-assembly stations at appropriate points adjacent to the main lines.

Testing of Assembled Components

Considerable attention is given to the testing of the various assembled units of each car and of each completed car. Each instrument panel, for instance, is tested as one unit in a special jig. The ignition warning is checked, as are the readings of the fuel and oil gauges, the speedometer is tested thoroughly, and must not read below $29\frac{1}{2}$ or above 31 m.p.h. when the master meter shows 30 m.p.h. Every rear-axle assembly is tested individually at speeds up to the maximum at which it will be called upon to run under service conditions and at varying loads. Detection of noise or vibration is by sensitive electrical instruments, this recording of sound by measurement in " phons " being used instead of relying upon personal impression. Engines are connected in pairs in the test-house, flywheel to flywheel, with reverse gear, each partly run-in engine, working under its own power, is used to drive a new unit which is flooded with filtered oil until a sufficient degree of freedom has been attained, when this in turn, under its own power, drives another new unit. Inspectors then " silent test " engines in special " quiet rooms." Completed engines after passing all tests are sent to the assembly lines.

Space does not permit of giving even brief details of many other interesting operations and the manufacturing technique necessary in the building of a modern motor-car, but mention may be made of the new paint and trimming shops where bodies are taken by power-driven conveyers through the specified spraying and drying booths. Paint in its various colours is supplied to each spray booth from one distributing centre. Any one colour is served from power-

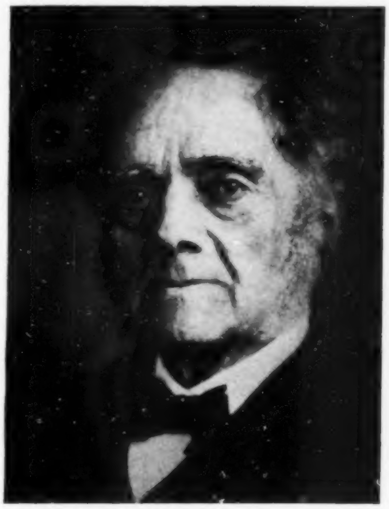
One of the inspection beds at the end of each machine line, where every operation is carefully examined before being passed to the next division.

driven mixer-containers and is distributed to the various spray booths by means of copper piping, a complete flow-and-return circuit being installed for each colour. After spraying, drying and polishing, the bodies pass by overhead conveyers to the trimming department where upholstery and fitments are fixed.

We take this opportunity of expressing thanks to the Humber-Hillman Co. for permission to publish this article and we are indebted to Mr. E. W. Hancock, works manager, Mr. T. H. Oakley, advertising manager of the Humber-Hillman companies, also Mr. Berrisford and Mr. Child of the Humber staff, for their active assistance and co-operation.

George Kent's Centenary

An old firm with a modern outlook which has developed industrial economy by the application of scientific methods of measurements and control and for a hundred years the successful results achieved have depended on father and son. The progress of this firm is briefly reviewed.



The founder of the firm, Mr. George Kent

The present Managing Director, Sir Walter Kent

AN achievement of unusual interest is that of the firm of George Kent, Ltd., of London and Luton, founded just a hundred years ago by George Kent when he was about forty years old. It is of unusual interest because the firm has been controlled for the full hundred years by father and son—George Kent and his son, Sir Walter Kent, C.B.E., the present chairman and managing director. There must be few firms remaining in this country in which successful business results have depended upon father and son for such a long period, and a brief summary of the history of this firm will be of interest because many of the earlier products were familiar in many households.

It is significant to note that the business activities of George Kent can be attributed to a date earlier than 1838, for he commenced business in 1834 as a blind-maker. Since the inception of the firm, however, one common purpose seems to have taken priority throughout its business life—that of economy and control of liquids. From the early days of George Kent's "Milk Saver"—a small piece of earthenware placed in an ordinary saucepan—has been developed the equipment for the automatic control of a plant producing steam of 200,000 h.p., or more.

Born in Goudhurst, Kent, in 1806, George Kent was the pioneer of many domestic labour-saving inventions, and his name was particularly widely known in connection with the rotary knife-cleaning machine which he patented in 1844, and which was eventually rendered obsolete by the introduction of stainless steel cutlery. He was among the first to introduce the domestic refrigerator or ice-safe, a ventilated refrigerator being patented in 1868.

The knife cleaner and the refrigerator were the main lines produced by the firm, and premises were opened in the Strand for the sale of these and other labour-saving devices. A boy of twelve was given employment and stayed with the firm for sixty-six years, achieving an honourable and important position and becoming a magistrate and an alderman of Luton. This was Charles Escott.

Other interesting personalities are Thomas Cooper, who was George Kent's first foreman, and who was followed by his son and then by his grandson. The three successive generations of this family gave loyal service to the firm for more than fifty years each.

In 1867 George Kent was joined by J. W. Sutton, another loyal and hard-working member of the firm who was still doing a full day's work at Holborn until just before he died at the age of ninety-three. The present Sir Walter Kent joined the firm in 1876, at the age of eighteen. The business grew, additional premises were taken in Holborn, and in 1883 the water meter was included in the firm's activities.

Successful contesting of the basis of water-rate valuation attracted Mr. Sutton's attention, and the idea of substituting a water meter for the water rate was the basis of the development of the company's multifarious activities to-day, the firm now supplying instruments for the measurement and control of fluids of every possible kind, and more particularly water (both in pipes and open channels), steam, gas, air, oil and sewage.

At the 1885 Inventions Exhibition George Kent realised the possibilities of the design of a patent water meter working on a semi-rotary principle. He bought the world patents, and that was the first "Uniform" meter. The Venturi meter was added to the firm's products in 1893. In 1910 the engineering side of the business was still mainly confined to measurement of the flow of water. In 1908, however, the research department had been considering the possibility of using the Venturi principle for the measurement of air. The whole air supply to the Rand mines from the Victoria Falls Power Company was measured and paid for according to the records of Kent-Venturi meters, which made automatic correction for the effects of temperature and compression, and recorded the quantity delivered in terms of volume at a specified temperature and pressure. These meters are still being used for this purpose. From this beginning the measurement of many other gases, and of steam, was successfully

accomplished. It was about this time that the new works at Luton were opened.

The Great War intervened, and the resources of the Company were accepted for the production of some dozen different types of fuses. In 1919 the problem of restoring pre-war trade was faced, and gradually overcome. The great increase in the use of scientific methods in all phases of industrial production resulted in the firm developing a whole range of instruments for the measurement and control of the flow of fluids. The products now include instruments for the control of flow, pressure and temperature of liquids and gases at various stages of the refining processes in the oil industry, automatic boiler control equipment, and delicate mechanism for pressure control in which conditions are maintained within a limit of error of less than 1%, however much or however sudden the load may vary.

Such factors as forced draught, induced draught and rate of fuel supply had to be taken into account, and all are automatically controlled through the master controller and sub-controllers arranged for either complete or partial control. Electricity and chemistry called for measurement of *p*H, and the "Multelec" was produced, capable also of being used for gas analysis and the measurement and control of conductivity, temperature and turbidity. Just recently the uses of this instrument have been extended to the measurement of CO_2.

One of the most popular steering gear assemblies for cars is the "Bishop." This type of steering gear is manufactured in a special building, where the output is over 4,000 gears per week. Other departments of the present business include those for the manufacture of fractional horse-power motors and of clear-view screens used in most of the navies and mercantile marines of the world.

It has only been possible to give a few facts that represent landmarks in the history of this firm. Progress has been gradual but persistent, and the number of employees has grown to 1,750. The firm has concentrated on the manufacture of control equipment for almost every fluid requirement; this multiplicity of instruments has one great value, it satisfies the desire of the consulting engineer who designs a plant, or the works manager who controls a process, that, as far as possible, all instruments of measurement and control shall be supplied by one firm, which also simplifies the allocation of responsibility.

To-day the Luton works occupies nearly 7 acres, and has a floor space of over 280,000 sq. ft. It is the largest business in Great Britain devoted to the manufacture of industrial instruments and controllers. In order to cope with the unusally scientific and varied character of the work involved, a technical staff of the highest order has been brought together. There is a large research staff, with laboratories, for the purpose of investigating the requirements of the latest processes, and determining the best methods of measurement and control. Thus this century-old firm remains in the forefront, meeting the requirements of the engineer and contributing so much to industrial economy by the application of scientific methods of measurement and control.

Electric Furnace Demonstration Facilities

Owing to the continued expansion of Messrs. Wild-Barfield Electric Furnaces, Ltd., and the subsequent increased demand on available space at the works, facilities for demonstrations have been continually curtailed. While the greater use of electric furnaces has lessened the necessity of demonstrations, many purchasers prefer to see and try a particular type in which they are interested. It is interesting, therefore, to note that this firm have taken premises adjacent to the works, where a wide range of their standard types of heat-treatment furnaces is installed.

Adequate facilities are provided to enable a variety of work to be dealt with, and the furnaces are at the disposal of any firms interested in extending their heat-treatment plant. The upper portion of the new premises is reserved for the firm's new research department, now nearing completion.

Forthcoming Meetings

INTERNATIONAL ENGINEERING CONGRESS

A NUMBER of engineering societies have co-operated to organise concurrently with the Glasgow Exhibition an International Engineering Congress. This will be held on June 21 to 24, inclusive, and an interesting programme of technical sessions, visits to works, excursions and social events has been arranged.

The technical addresses will be delivered at their concurrent sessions and the subjects include: "Some Recent Developments in the Iron and Steel Industry in Britain" by A. McCann, D.Sc. and T. W. Hand; "Materials Research and Modern Machining Practice" by Prof. Dr. A. Thum; "The Building of Ships—A British Survey" by Sir James Lithgow, Bt., M.C., D.L.; "Naval and Mechanical Constructions in Italy" by Gen. G. Rota, R.I.N.; "The Use of British Coal—a Review and a Forecast" by Sir Richard A. S. Redmayne, K.C.B.; "Progress of the Internal Combustion Engine during the last Twenty Years" by H. R. Ricardo, B.A., F.R.S.; "Technical and Economic Developments in Electrical Engineering" by S. B. Donkin; "Some Views on the Problem of Electricity Generation and Distribution in France" by E. Mercier; "Gas—Yesterday, To-day and Tomorrow" by Sir David Milne Watson, Bt., M.A., LL.B.; "Recent Developments in the Gas Industry in Canada" by J. Keillor; "Town and Country Planning and its Relation to Industry" by G. L. Pepler, F.S.I.; "The River Clyde and the Harbour of Glasgow" by A. C. Gardner, F.R.S.E.; and "International Air Transport" by Rt. Hon. Lord Sempill, A.F.C.

A.S.T.M. ANNUAL MEETING

IN the seventeen formal sessions of the Forty-first Annual Meeting of the American Society for Testing Materials to be held at Atlantic City, June 27 to July 1, inclusive, there will be presented 104 technical papers and reports covering important topics on a large number of engineering materials. Dr. A. E. White, A.S.T.M. President, in his annual address will discuss "Industrial Research." Dr. Albert Sauveur, Metallurgical Engineer and Professor Emeritus, Harvard University, will deliver the Thirteenth Edgar Marburg Lecture. His topic, "The Torsion Test," is one on which there is a conspicuous lack of information in the technical literature.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

ON Tuesday, June 28 next, Rear-Admiral George H. Rock (CC), U.S.N.(ret.), late Chief of the Bureau of Construction and Repair, United States Navy, will visit Newcastle to receive the Institution's Diploma of Honorary Fellowship. He will be accompanied by a representative number of members of the Society of Naval Architects and Marine Engineers, U.S.A., and the following programme has been drawn up for their entertainment:—

10-30 a.m. Presentation of Diploma of Honorary Fellowship of the Institution at King's College.

12-45 p.m. Civic Luncheon to Institution's guests.

2-15 p.m. (*a*) Trip on the Tyne. The Tyne Improvement Commissioners are kindly granting the use of their launch *Sir William Stephenson* for the purpose.

(*b*) Visit to the Roman Wall or other places of interest.

7-30 for 8 p.m. Dinner by Institution, followed by Dance.

The party from the United States will include a number of distinguished American shipbuilders and engineers, headed by the President of the Society of Naval Architects and Marine Engineers, Mr. Joseph W. Powell.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Metallurgy and Aircraft Construction

The Value of Research

IT is sometimes forgotten that research is another form of pioneer work, and subsequent development is frequently slow because of the continued need for further research. Discoverers of new lands, for instance, were able to give very little information about their discoveries. In many cases the extent of the discoveries and an approximation of their potentialities were not appreciated for years afterwards, and then only after pioneers had prepared the way for more general development by further investigation. In a similar way, research constitutes the framework that gives fundamental support to the continued development of industry. Thus, primarily, the research worker is a pioneer following up discoveries and investigating them with the object of ascertaining facts; in this way, new problems are continually being presented to research workers, and the results of their investigations provide the knowledge which can be applied to industry.

The application of the results of research is frequently very slow and discouraging, but Dr. H. J. Gough, in his recent Wilbur Wright Memorial Lecture before the Royal Aeronautical Society, shows what achievements have been made in the application of research to materials for aircraft construction. In reviewing the materials used he made a comparison between the principal materials used in the 1903 Wright engine and typical materials used to-day. In producing their famous biplane, and achieving their historic flight, the Wright brothers started a quest for even lighter and stronger materials with such far-reaching results that have made possible not only the aircraft of today and tomorrow, but have also proved of inestimable value to every other branch of engineering construction and technical development. Metallurgical research has been largely responsible for the remarkable progress so far made. In a relatively few years the application of the results of this research has effected a change; they have seen the relinquishment, temporary or permanent, of the position held by steel as a structural material for aeronautical purposes, and the use of light alloys has become general.

The constant urge for ever increasing power, so largely accelerated by the use of improved fuels and supercharging, has, as far as the engine materials of construction are concerned, introduced two primary problems which may be classed as thermal and mechanical. Only those materials best suited to meet these searching demands can find a place in high-duty engines and the use of the various materials available is clearly determined, with regard to general aircraft structure, however, there are many excellent examples of construction which differ fundamentally in the materials employed.

After a survey of the metals and alloys available for aircraft purposes in 1938, Dr. Gough states that the first impression is one of admiration for what has been accomplished, followed immediately by a realisation of the immense possibilities that remain for future research and development. The value of research to the aircraft industry in the past has been of a high order, and, in view of what has been done, there can be no doubt that, both now and in the future, even more valuable work will be accomplished and there is no question that this industry will absorb the results. In some instances the needs of an industry are in advance of research, whereas in others research is in advance of industry. In the former instances the applications are known, and new developments are readily grasped and given practical tests almost at once, to discover the extent to which they meet demands and also to overcome difficulties that are almost invariably encountered in practice. When the results of research are in advance of industry, and no direct application seems to present itself, there is a danger that the work may be overlooked and forgotten.

The success obtained in recent years in isolating a few metals in a high state of purity and determining their physical properties, Dr. Gough regards as making a first step in a fundamental aspect of scientific metallurgy. The fundamental knowledge of the properties of metals and their alloys is very limited. To make a general systematic study of metallic alloys is very involved and the difficulties are stupendous in view of the possible combinations. The task of even calculating the number of alloys that might be produced from all the varying combinations of metals or metalloids makes one realise that "hit-or-miss" methods are frightfully inefficient in searching for alloys having special properties. It is true that rich rewards may result from the steady pursuit of "hit-or-miss" methods of making a quick survey of an alloy system by determining the physical properties of a number of compositions covering what appears to be an attractive field. In fact, in the history of metallic alloys, most of the real landmarks relate to discoveries obtained before modern scientific methods were even available. Nevertheless, we need a knowledge of how atoms and molecules of metals arrange themselves when alloyed together, and how each arrangement affects physical properties. When this field is properly understood, it will be possible to predict from any combination of metals, what the properties of the alloys will be, and, conversely, given a set of physical properties, the alloy having these properties can be calculated. In so many instances slight differences in composition greatly reduce the value of a material and a bit of research work may just fail to be of an outstanding character as a result.

Fundamental research is primarily the work of purely scientific laboratories and many subsequent investigations are usually necessary before the results can be absorbed in normal production. So many conditions must be satisfactorily met before a designer will be prepared to change his material; assimilation in industry will necessarily be slow because a variation in technique from that which has been customary is frequently involved. In connection with aircraft construction it must be admitted that the technique developed in the various manufacturing processes has contributed much to the progress so far achieved.

It is likely that the future will disclose great developments by the improvement of existing alloys by relatively small alterations in composition, by suitable heat-treatment and by refinements of manufacture; on the other hand, developments may amount almost to a revolution in metallurgy, by the production of alloys by the sintering of powders, but persistent metallurgical research is necessary to meet further demands for even better materials than those now available.

Fifth Report of the Corrosion Committee

This Report, which is the work of a Joint Committee of the Iron and Steel Institute and the British Iron and Steel Federation, gives a very detailed account of work carried out under six main headings: atmospheric corrosion, marine corrosion, laboratory and fundamental work, protection coatings, collaboration with other committees and investigators, and various other matters considered or investigated by the Committee. The work done is very extensive and can only be reviewed very briefly here.

QUANTITATIVE results are given for the loss in weight of specimens of various rolled irons and steels in the unpainted condition after up to 5 year's atmospheric exposure at ten stations in Great Britain and overseas. These show that the rate of corrosion of unprotected mild steel exposed vertically in the open atmosphere ranges from practically nil at Khartoum to a maximum of 0·0055 in. per annum at Sheffield. There is some evidence of a decrease in the rate of corrosion with the duration of exposure. Only very slight pitting occurred on the materials tested. Swedish wrought iron, which contains but little slag, proved to be the most corrodible, showing that purity alone does not confer resistance to corrosion. The addition of 0·6% of copper to this material caused a very marked improvement. Ingot iron has proved slightly less corrodible than mild steel, on the average by about 7%.

Of the low-alloy steels tested, that containing 1% of chromium corroded about 30% less than ordinary mild steel at Sheffield, but was slightly inferior to a steel containing 0·5% copper. The joint addition of copper and chromium in small amounts caused a reduction in the corrosion greater than that due to either of the individual additions. The improvement due to copper additions did not occur with specimens exposed in the humid and polluted atmosphere of a railway tunnel. The effect of copper additions was not so marked on specimens descaled before exposure as on as-rolled ones. Provisional results of observations made on the painted specimens and stands are also given.

The atmospheric pollution records are brought up to date by the inclusion of further analyses of rain-water samples from the four main stations and the result for the corrosion of the small control specimens of ingot iron and zinc. The examination of steel sleepers, after approximately 5 years' service in five areas of the Great Western Railway system, confirms the results of earlier tests, namely, that general corrosion should not be a factor affecting the life of steel sleepers, and that the use of copper-bearing steel is advantageous in the open but not in tunnels.

Marine Corrosion

Further observations on steel plates built into the hulls of the barge *Cactus* and of the Admiralty trawler, H.M.S. *Basset*, are recorded. The general conclusions, that most corrosion is initiated by mechanical damage and that with careful maintenance serious trouble should not occur under normal circumstances, remain unchanged. As a result of such maintenance, initial differences in the surface condition of the plates seem to become relatively unimportant.

Laboratory Research

This Section includes six Papers describing work carried out by, or reported to, the Sub-Committee. Two papers report work carried out at Cambridge University. The first describes how thin oxide films on metal can be transferred to celluloid. The examination of such films is thereby greatly facilitated and the procedure constitutes an extremely valuable new method of research. The second paper summarises work on the electrometric study of the growth of oxide films on iron.

The next two Papers refer to corrosion tests on wires by the decrease-in-breaking-load method. The results, after 5 years' exposure at Farnborough and Calshot, and after 2 years at Sheffield University are in satisfactory agreement with those of the Committee's main tests on atmospheric corrosion by the loss-in-weight method.

The fifth Paper records further observations on small painted specimens exposed at Birmingham and Farnborough. Earlier conclusions as to the effect of surface condition and the use of an inhibitive primer are substantiated. It may be noted that two coats of paint applied to pickled wrought iron were still protecting the metal adequately after 5 to 6 years' exposure at Birmingham. The sixth Paper details results of experiments on the rate of dissolution of mild steel in sulphuric acid. The experiments are preliminary to further tests on the effect of inhibitors.

Protective Coatings

The work of a Sub-Committee on this subject is described in the first part, which concludes with a statement of their present views concerning the best procedure for the painting of iron and steel exposed to atmospheric corrosion. In brief, descaling is recommended, followed by the application of priming coats of an inhibitive character, and all painting should as far as possible be carried out under dry conditions. The second part reviews modern painting practice as revealed by the replies to questionnaires circulated by the Sub-Committee to various large users of structural steelwork. The third part deals with the surface preparation of steelwork prior to painting. Various methods of descaling are considered, including pickling, sand- or shot-blasting, wire-brushing by hand or machine, and the use of abrasive wheels or discs. The use of inhibitors or panel washes is discussed. Also included in this Section are three communications from individual authors.

Other Information Submitted

Four cases of corrosion reported to or investigated by the Committee are described. The first two refer to corrosion in concrete. In one case mild-steel pipes and tubes buried in a concrete floor had been perforated by corrosion, which was found to be due to an unsatisfactory concrete aggregate and bad drying conditions at the time when the concrete was laid; in the other, severe attack on wrought-iron reinforcement girders after 48 years' service was traced to the presence of coal breeze in the aggregate. The third case concerned the severe corrosion of some steel sleepers that occurred in a railway line near the sea. In the fourth case a correspondent drew attention to the rapid corrosion of ships' plates in Indian rivers, which he attributed to bacterial action.

The Section concludes with brief accounts of the research work on corrosion in progress in several other countries, which are published as part of the scheme of international collaboration to which reference has already been made.

Special Report, No. 21; published at offices of Iron and Steel Institute, 28, Victoria Street, London, S.W. 1. Price 16s. (Members 10s.).

The Inspection of Raw Materials in the Aircraft Industry

By H. H. Jackson

Modern aero-engineering factories absorb such a large variety of materials that a highly efficient acceptance organisation is essential to ensure that the materials accepted are of the quality required in the finished products. In this article the checking and testing of various materials are discussed.

THE question of the acceptance of raw material to engineering firms, particularly those engaged in the production of aero-engines and aircraft, is undoubtedly of vital importance, in order to maintain the predetermined quality of the units or components manufactured. The modern aero-engineering factory absorbs such a large variety of materials for such a wide range of specialised purposes that a highly efficient acceptance organisation is justified and is essential to ensure that the materials accepted by the firm are of the quality required in the finished product. The organisation necessary for this function should consist of the raw material inspection department working in close co-operation with the design, laboratory and works departments, so that, in the first place, the standards required by these latter departments are thoroughly understood by the raw material inspection department. For instance, on one component alone the Design Department will require the observance of dimensional limits (the interpretation of which will require discretion); the laboratory may define a particular type of fracture and hardness range to be observed; whilst the works may require certain features essential to mass-production methods, such as machinability, consistency of material, dimensions, etc.

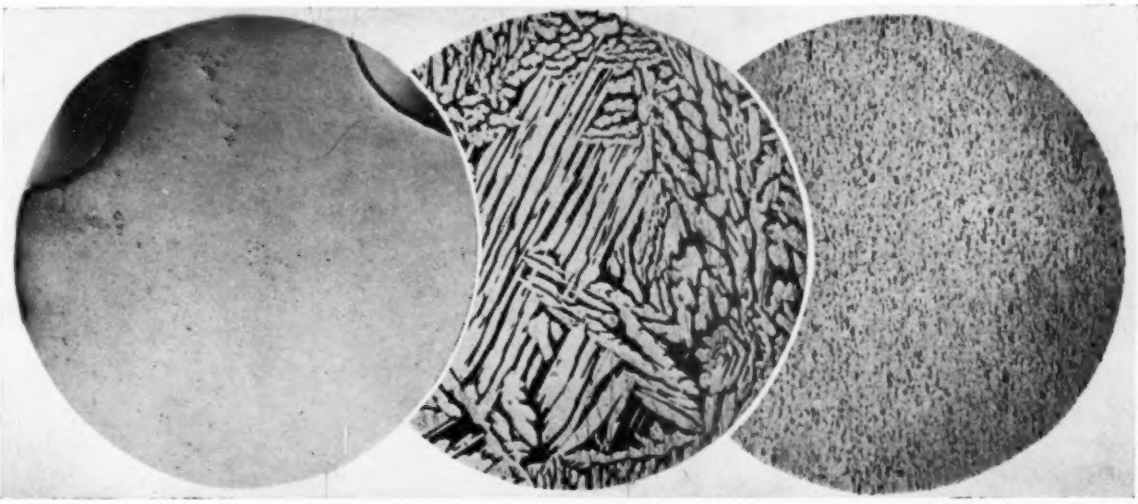


Fig. 1.—Porous area in magnesium-alloy casting. × 8.

Fig. 2.—Micro-section of aluminium-bronze bar which showed "coarse fracture" in testing. × 56. Physical properties: max. stress 32.48 tons/sq. in., elongation 29.5%. Brinell hardness 131.

Fig. 3.—Micro-section of aluminium-bronze bar which showed "fine fracture" in testing. × 56. Physical properties: max. stress 38.5 tons/sq. in., elongation, 15/%. Brinell hardness 170.

Material Checking

A number of components will be received by the firm in the partly finished condition, and the dimensional inspection of these parts will be of an entirely different standard to that applied to the inspection of rough forgings, castings, etc. The use of discretion in dimensional checking must be based on experience in design, service requirements, and works practice; and it is proposed not to consider this aspect of material acceptance, depending as it does on the functioning of individual components.

The tests performed to ascertain the quality of raw material are interesting, and are made mainly to detect the following faults:—

(*a*) *Metals.*—

1. Unsound material, blow-holes, porous areas, etc.
2. Excessive inclusions of foreign material, slag, piping, etc.
3. Surface defects, cracks, laps, tears, etc.
4. Unsuitable grain-flow of forgings.
5. Incorrect heat-treatment.
6. Incorrect material.
7. Inferior physical properties.
8. Possible omission of any specified treatments—e.g., plating, tinning, etc.

All the major members and components will be included in this group, and it is by far the most important.

(*b*) *Non-metals.*—This sub-division comprises material or components formed from rubber, felt, Perspex, cloth, plywood, plastics, etc.; and tests on these are usually made to confirm the homogeneity of the material; freedom from tears, blemishes and similar imperfections; tensile tests to a specification agreed with the supplier; or special tests, such as the visibility through Perspex, elasticity of rubber afterageing, etc.

(*c*) *Materials Used in Works Processes.*—The importance of certain of these materials may warrant special attention and checking, particularly such materials as Stellite

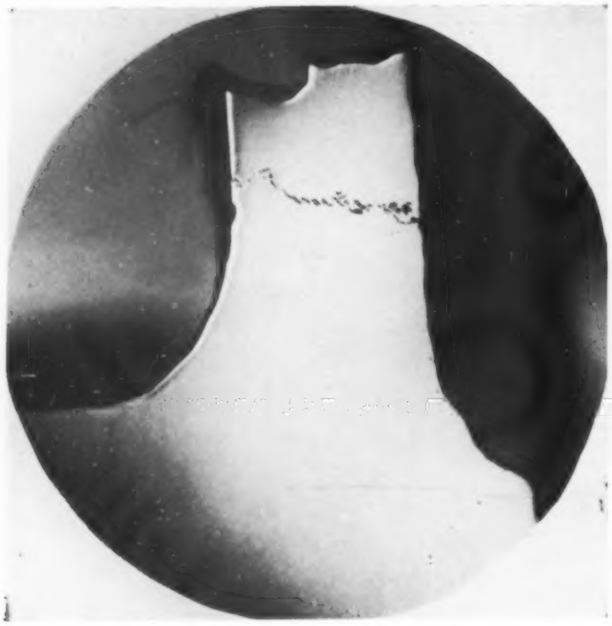


Fig. 4.—Section through magnesium casting. External examination showed apparent surface crack; subsequent mico-examination reveals chain of internal checks. × 8.

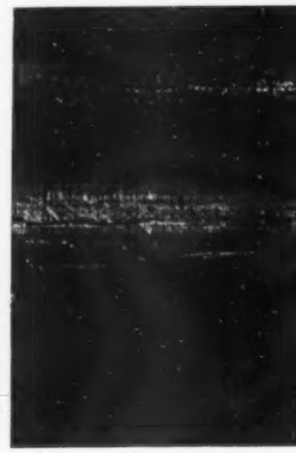


Fig. 5.—Longitudinal defects in bar shown by Electroflux examination. × 8.

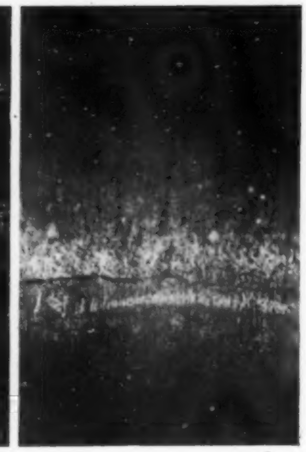


Fig. 6.—Extended defect in bar shown by Electroflux examination. × 8.

enamels, fluxes, "Brightray," honing grit, welding rods, paints, varnishes, lubricating oil, etc. The testing of this group usually consists of confirming analyses, specification values, or special tests that have been agreed upon with the suppliers.

The Supplier and the Manufacturer

The very first phase of ensuring consistent deliveries of satisfactory material commences with the placing of the order with a supplier. No pains should be spared to co-operate with the suppliers to make them very familiar with the standards of inspection that are required. When borderline cases arise, they should be discussed and samples retained by both sides to be used as standards for future reference. These samples are infinitely more valuable and satisfactory as standards than such ambiguous terms as "clean steel," "sound fracture," "free from defects," and so on. For example, the question of the required cleanliness of a steel may be settled by reference to one of the arbitrary methods of assessing the quantity of non-metallic inclusions by an "inclusion count."

In the case of certain components, it may be necessary to institute some degree of control of the material whilst it is still in the hands of the supplier. For such parts as propeller blade blanks, cylinder barrels, spar sections, crankshafts, etc., a sample of the metal from each cast should be forwarded to the manufacturer for approval before forging operations are commenced. The test-pieces must include the centre of the ingot, and they should be hot-worked and heat-treated relevant to the component in question. In addition to the physical and chemical tests, it is common practice to demand sulphur prints from the last ingot of a cast; and no further work is done with that cast by the supplier until the approval of the manufacturer has been obtained.

Inspection for Material Defects

The detection of unsound material is largely confined to the examination of castings for shrinkage cavities, draws, blowholes, etc., since these defects are not found in forgings, pressings, or extruded sections except under exceptional circumstances. This unsoundness is to be commonly found where a comparatively thick section is reduced to a thinner section, as in Fig. 1. In aircraft engineering, castings are confined to the non-ferrous metals, particularly to the light alloys, and although sound aluminium alloy castings are now common practice, there appears to be much more difficulty in making a really sound magnesium alloy casting. The chief casting characteristics of the light alloys are their low specific gravity and their affinity for nitrogen, oxygen, and other gases—and each of these factors is known to be conducive to porosity.

The above factors should be taken into account when inspection reveals local unsound areas in light alloy castings. Special precautions are observed in the casting of magnesium alloys to preclude absorption of gases and interaction of the metal with moisture in the sand. A relatively large quantity of flux is employed to minimise contact of the melt with the atmosphere, and owing to the low specific gravity of these alloys, particles of flux may easily be entrapped in the solidifying metal. Both of the above faults are minimised in die-castings, where the metal is rendered more dense, and the dies are cleaner.

It is interesting to note that definite efforts are being made to supersede the practice of fracturing light alloy castings in order to detect regions of unsoundness by instituting a system of radiographical examination of all castings leaving the foundry. It is necessary to subject magnesium castings to an impregnation process in order to increase the ratio of the densities of air and the metal.[1] Such an innovation is to be welcomed as a more scientific method of control; and when the process becomes accepted practice it will constitute a positive and non-destructive system of inspection.

In the past, American firms appear to have been more progressive than ourselves in commercialising radiographical examination for inspection purposes; several of their leading firms have standardised this system in the past three years.[2, 3] It is noteworthy, however, that British aircraft firms are now relying more and more upon inspection by radiography. The interpretation of radiographs is by no means universally understood, and much authentic investigatory work remains to be done before it will be possible to assess inspection standards by radiographical examination.

Actually the fracture test constitutes a very useful method of determining the properties of a batch of material, providing that a representative percentage has been taken for test. Inclusions, piping, coarse structure, segregation, are easily recognised; and the correlation of micro-examinations or physical properties with fracture types

1 "The X-ray Inspection of Magnesium Castings." N. C. Hypher. METALLURGIA, April, 1935.

2 "Radiographs of Metal." K. R. Van Horn. *Metal Progress*, August, 1936.

3 "X-rays Among the Metals." Ancel St. John. *Metal Progress*, October, 1936.

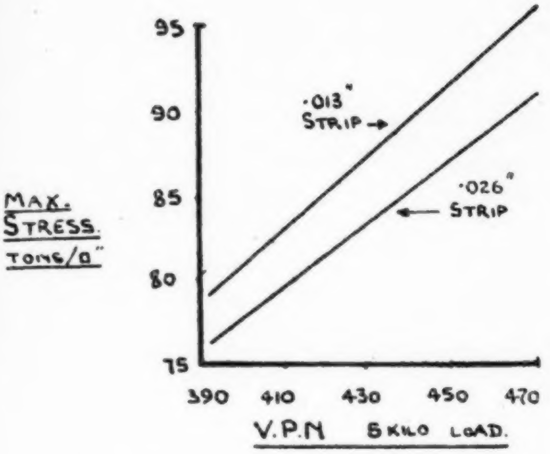
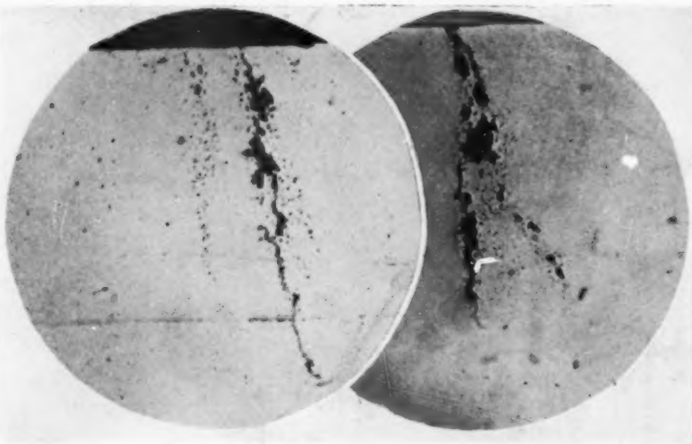


Fig. 9.—Discrepancy of conversion factors applicable to different thicknesses of air-hardening steel.



Figs. 7 and 8.—Cross-sectional photomicrographs of defects shown in Figs. 5 and 6. × 225.

make this test most reliable when performed by an experienced operator. Figs. 2 and 3 show micro-sections of aluminium bronze bars with coarse and fine fractures, and the corresponding reduction in physical properties in the coarse material are denoted. Again, laboratory investigation of a "short" fracture of a die-casting may show the cause to be due to any of the following: Wrong heat-treatment, inadequate casting pressure, wrong material, incorrect structure, excessive inclusions or areas of minute pores, etc. Fracturing, then, may be regarded as a good method of discovering the presence of faults, although it is advisable not to specify the nature of the flaw without confirmation by the microscope or mechanical testing. The Hounsfield tensometer can be used with advantage in borderline cases to determine the actual detrimental effect of the faults by making test-pieces from good and defective components.

Surface Defects

The surface defects most frequently encountered are ingot imperfections made manifest by working—e.g roaks and seams in steel bars, spilleys in non-ferrous bars, piping folds, laps and draw-marks. The criterion in assessing these depends upon the extent of subsequent machining operations; and representative samples of faulty material should be split open or cross-sectioned to determine the effective depth of any skin defects, Fig. 4. The bend test is a most satisfactory means of detecting surface flaws in sheet material, providing the specimen is bent slowly and is examined progressively.

With regard to aluminium alloy forgings, sheets, bars, etc., the presence of surface defects is not so obvious as in the case of steel; but it has been found that anodising will render the following faults much more conspicuous: laps, inclusion specks, cracks, laminations, etc. Incidentally, the grain-flow of a polished surface will be clearly revealed by anodising; indeed this process is most useful in developing the conspicuousness of surface defects found in aluminium alloys, and may be used to decide many doubtful cases.

A useful inspection appliance applicable to magnetic steels is the "Magnaflux" machine, in which a component is magnetised and then covered with a solution containing finely-powdered iron. The iron dust collects at the magnetic poles made by the edges of cracks and discontinuities, revealing them very distinctly. Although this machine is most useful for the inspection of finished components, stampings, etc., that will not be heavily machined can be examined for surface flaws after painting with aluminium paint. A modification of this apparatus suitable for the inspection of bar material for longitudinal flaws, is the "Electroflux" machine. This has been found to be most efficient in the detection of surface flaws, as it shows the presence not only of cracks, but surface inclusions, roaks, and similar defects. Figs. 5 and 6 show photographs of surface defects on bars as revealed in the "Electroflux" machine, whilst Figs. 7 and 8 show micro-sections taken at right-angles to these. It will be seen that the defects are actually longitudinal streaks of inclusions which, incidentally, would have been removed in subsequent machining operations.

Wire for the manufacture of springs must be subject to a rigorous inspection, as minute flaws are aggravated in spring coiling. Surface defects, such as seams, cracks, etc., may be revealed by acid etching, or a suitable bending or coiling test may be devised. Other tests on highly-stressed spring wire should include tensile tests and micro-examination, the latter being essential to check the cleanliness and uniformity of the material. The approval of finished springs consists in confirming rate of compression or tension, examination for surface faults by a special type of "Electroflux" machine, and an occasional micro-examination.

Physical Testing

The hardness testing of batches of stampings, etc., is now so universally accepted as a means of revealing the uniformity of material that it is sometimes forgotten that the scope of this test has very definite limitations. For instance, several classes of steel may easily be suitably heat-treated to give precisely the same hardness, and yet it is not always appreciated that hardness testing is an absolute check on neither material nor heat-treatment, but merely serves as a guide to detecting cases of non-uniformity, mixed materials, etc., to which more conclusive tests can be applied—e.g., analysis, physical tests, micro-examination. It has been found time and time again that serious discrepancies in hardness values can occur by employing various methods of testing any particular material, and it is very advisable to specify to material suppliers the exact nature of any hardness tests used as a basis for the acceptance of their material.

In any case, the assignment of a specified hardness range to a certain class of raw material should not be undertaken until sample components and test-pieces have received their correct heat-treatment under the supervision of the laboratory, and until it is proved that the required physical properties of the material will be characterised by a certain hardness range. This hardness range should be assessed on the type of testing machine that will be ultimately used for the routine inspection of future deliveries; as "hardness conversion tables" are by no means capable of being relied upon unless actual experience proves them

applicable to the component in question. Another "conversion table" frequently misused even by some of the most experienced engineers is the series of relationships between the tensile strength and hardness of steel, in which the following factors are generally employed—for carbon steels, 0·23; alloy steels, 0·22; and high-tensile alloy steels, 0·21. Actually, it has been found that these relationships vary not only for different classes of steel, but also for different heat-treatments of the same steel; indeed, variations have been found in the case of different thicknesses of air-hardening steel which have undergone identical heat-treatment. It will be seen by reference to Fig. 9 that the conversion factor varies from 0·191 to 0·202 for sheet thicknesses of 0·026 in. and 0·013 in. respectively.

The Chemical Aspect

The functions of the chemical laboratory with regard to the acceptance of raw material are largely confined to chemical analysis of materials; and to the testing of plated deposits, sprayed coatings, etc. With the exception of the interest taken in adopting spectrographic analysis for routine work, there have been no recent outstanding developments in commercial methods of analysis; whereas several original testing methods have been devised for the inspection of electro-deposits. The tests which show most promise of extensive application are the electro-magnetic and magnetic methods introduced by Tait, Hoare and Chalmers,[4] these being non-destructive and applicable to the measurement of non-magnetic coating on a magnetic base metal. It is probable that the "spotting," "stripping," and jet-tests now in common use will be superseded by developments of the non-destructive tests mentioned.

Non-metallic Materials

The Natural and Synthetic Plastics.—Turning now to the testing of non-metallic aircraft materials, one factor which is evident is that much investigatory work remains to be done in order to standardise the testing of the rapidly increasing family of plastics, transparent materials, and the like. Test-pieces for these materials will have to be standardised as in the case of tensile, bending, and impact test-pieces for metals; and, as their applications increase, these plastics will have to be subjected to an inspection commensurate with the importance of the components made from them. At present, their use is confined, with few exceptions, to relatively low-stressed components; but the possibilities of this group of materials are so promising that their application to constructional parts seems imminent, in which case special tests will have to be devised to estimate the serviceability of the various materials, in much the same way that specialised methods of testing metals have been inaugurated—e.g., electro-fluxing, magnetic analysis,[5] etc.

Wood versus Metal.—In spite of the fact that the last five years have witnessed a decided trend towards the light alloys as constructional materials, wood still finds application in the manufacture of the smaller types of civil aircraft, and is most useful for the small-scale production of these. Wood is by no means an abandoned material in the aircraft industry, as its specific tenacity and low cost are undeniable merits, even when allied to such unfavourable characteristics as unhomogenity, progressive moisture absorption, comparatively rapid deterioration, and the relative difficulty of joining and fabricating highly stressed wooden structures. The testing of wood has reached a comparatively advanced state of standardisation in America, where the American Society for Testing Materials has detailed the following tests: Major bending, compression perpendicular and parallel to the grain, hardness, shear parallel to the grain, moisture content, impact, bending, cleavage, shrinkage etc.[6]

Experiments with specially treated wooden airscrew blades are being made which may minimise or even obviate several of the inherent disadvantages of wood as a constructional material. By impregnating the wood with resin and subsequently compressing it under heat, it has been found possible to manufacture "strength-graded" woods which combine the advantages of both woods and synthetic plastics. These materials show so much promise that it may shortly be necessary to standardise methods of tests for them. Such tests will no doubt compromise the existing tests on wood and plastics.

Other Future Trends

In addition to the future tendencies indicated above, the tests which appear to be most suited to eventual adoption for routine checking are: Tests at elevated temperature, determination of damping capacity, and an arbitrary form of wear test. The adoption of such tests depends largely on the question of suitable and standardised forms of testing machines, which must be reasonably cheap, robust, and reliable, so that the actual testing need no longer be confined to the skilled laboratory worker. One can anticipate that when such machines are introduced into general engineering inspection practice, the introduction will be made through the aircraft industry, which has in the past been responsible for developing so many inspection procedures and methods which have later been adapted to other branches of engineering.

The Shorter Process

Flame Hardening

ONE development of flame or torch welding is the mechanically-controlled "Shorter" process which has been described in this journal.* In brief, it is a method of hardening the wearing surfaces of ferrous metal parts, such as for machines, by controlled heating and quenching, and can be applied to parts made in cast steel, plain or alloyed, forged steel, cast iron, semi-steel, provided that the composition of the metal is such as to make it responsive to hardening by heating and quenching.

A considerable depth of hardness with high Brinell is obtained, there is very little distortion, and it is claimed that the hardening is regular throughout. The process can be adopted for gears and other pinions, wheels and cams, shafts and journals, and for cylindrical details such as tyres and brake drums.

Three methods can be used for hardening shafts: either by progressive treatment round the periphery for large diameters, or by rapid rotation of the shaft giving continuous hardening round the periphery for diameters up to about five inches, and the other method is by progressive spiral treatment for the continuous hardening of long lengths of straight shafts or rollers. One interesting machine is that used for crankshaft pins and journals. This is the Shorter-Messer crankshaft machine which enables the pins and journals on the crankshafts located in the same plane to be hardened at the same time.

These, and details of other machines and applications are described and illustrated in a new leaflet issued by the Shorter Process Co., Ltd., of Sheffield, and in which the many and varied materials that can be Shorterised to prolong their useful life are given.

The Shorter machines are now supplied without licence agreement. The company will send trained operators to install the machines, where the quantity of parts to be hardened justifies such installation. In some cases it is possible to fix clients' own machinery with burners, and so adapt them for surface hardening. Prices and full particulars are available from the company's address at Savile Street East, Sheffield, 4, or through any branch of the British Oxygen Company.

4 B. Chalmers, W. Hoare, W. Tait. "Int. Tin Res. and Dev., Council" Tech. Publ. A 66.
5 A.S.M. Metals Handbook, p. 601.
6 A.S.T.M. Standards, vol. II. 1936.

* METALLURGIA, Vol. VII, No. 37, 34.

Materials of Aircraft Construction

A relatively few years has seen the relinquishment of the position held by steel as a structural material for aeronautical requirements. This was the view expressed by Dr. H. J. Gough, M.B.E., F.R.S., in his recent Wilbur Wright Lecture on the above subject before the Royal Aeronautical Society. In this article is given a brief review of the principal metals and alloys and their chief uses as described by Dr. Gough.

IT appears to be accepted that, given the same high degree of designing skill, a modern aeroplane could be produced equally efficiently, from aerodynamic and weight points of view, if constructed essentially of wood, steel, or light alloy, and excellent examples of each construction are in flight to-day. And yet the impression of the construction of 1938 is mainly that of light alloy. The all-steel aeroplane, brought to such a high state of perfection in the years immediately following the war, has temporarily at any rate, rather faded into the background. For reasons the replacement of the biplane by the monoplane with much deeper wings and subjected to increased loadings is partly responsible, while the really remarkable development of extruded light-alloy sections of simple shapes and tapering dimensions is undoubtedly exerting a profound influence on the whole situation; again, the "clad" light alloys offer such attractions as coverings in the marine atmosphere of this country. It appears most probable that this method of construction will persist for some time.

A general analysis is given of the materials used in three typical engines. This analysis is presented in Table II; it relates to the main engine only, accessories, etc., not being included.

Engine Components

The materials of which the aircraft engine is composed can be regarded as a triumph of metallurgical progress. A few components are mentioned which represent the results of extensive research devoted to meeting the strenuous working conditions imposed by the engine. The cylinder head of an air-cooled engine probably consists of a forging of aluminium alloy, specially chosen for heat resistance, heat conductivity and machinability allied with good physical properties; the outside will be cadmium plated. It is fitted with a barrel of Ni-Cr-Mo steel, the inner surface nitrogen-hardened to resist wear. The valve seatings are made of a special Ni-Cr-Mn steel, the composition of which confers an especially high coefficient of expansion, 0·000022, approximately equal to that of the aluminium alloy in which it is fitted, thus overcoming the one-time serious problem of maintaining a tight fit; the seat facing is able to resist the demands of impact, wear, erosion and corrosion by the protection afforded by a welded-on ring of "Stellite," an alloy of cobalt, chromium and tungsten. The valve guides will probably be of phosphor bronze or aluminium bronze. The exhaust valve itself, which has to perform what is possibly the most severe duty demanded of any component of a high-output engine, to the severity of which duty the employment of leaded fuels has so greatly contributed, consists of no less than five materials. The hollow body is an austenitic high nickel and chromium steel, the stem is nitrided, the valve facing is stellited, while the head is probably covered with an 80/20 Ni-Cr alloy, of which the valve body itself may, in future, be made; the cavity of the valve is partly filled with sodium to facilitate the conduction of heat from the head to the stem. The piston body is an aluminium-alloy forging, although magnesium-alloy pistons are being extensively developed and may become the piston of the future, provided certain difficulties are overcome. The gudgeon pin is of high-strength case-hardened nickel-chrome steel, while the piston ring, a most important component, will be of an alloy cast iron. With regard to the material of the connecting-rod, this will depend on the type of engine; to meet the severe service of the radial engine, a high tensile air-hardening nickel-chromium steel, having a tensile strength of more than 100 tons/in.^{2}, is used, while other rods for such an engine, also, the connecting-rod for in-line engines, would be a nickel-chromium steel of about 65/75 tons/in.^{2} tensile.

A material used for the crankshafts of both types o

TABLE II.

A GENERAL ANALYSIS OF THE MATERIALS USED IN THREE MODERN AERO ENGINES.

General Classification.	Type.	Engine A. (Radial Air-cooled). Number of Materials.	Engine A. Weight lb.	Engine A. % of Total Weight of Engine.	Engine B. (In-line, Liquid-cooled). Number of Materials.	Engine B. Weight lb.	Engine B. % of Total Weight of Engine.	Engine C. (In-line, Air-coole). Number of Materials.	Engine C. Weight lb.	Engine C. % of Total Weight of Engine.
	Cast Iron	2	5	0·5	—	—	—	2	2	0·1
	Carbon Steels	9	30	3·0	3	114·5	9·6	20	212	18·2
	Low Alloy Steels—									
	(a) Nickel	1	60		3	185		2	14	27·6
	(b) Nickel-chromium	5	180		2	123·5		6	308	
Ferrous	(c) Chromium	—	—	29·0	1	9	35·6			
Metals	(d) Chromiuum-molybdenum	1	50		1	92·5				
	(e) Chromium-vanadium	—	—		1	13				
	High Alloy Steels—									
	(a) Chromium	3	5	9·5	2	9	2·8	10	10	2·2
	(b) Nickel-chromium	1	90		2	24·5		2	15	
	Aluminium Alloys—									
	(a) Castings	3	200	50·3	1	440	47	4	221	33·7
	(b) Forgings, etc.	6	303		5	114·5		16	172	
Non-	Magnesium Alloys—									
Ferrous	(a) Castings	3	31	3·2	—	—	—	1	168	14·6
Metals	(b) Forgings, etc.	1	1					1	2	
	Copper	1	3	0·3	1	9	0·7	2	1	
	Brass	4	7	0·7	1	4·5	0·3	10	7	3·4
	Bronze	5	30	3·0	3	44	3·7	12	32	
Non-Metallic	Rubber, Bakelite, etc.	—	5	0·5	—	3	0·3	8	3	0·2
	Totals	44	1,000	100	27	1,186	100	96	1,167	100

engine is a chromium-molydenum steel, having a tensile strength of 55/65 tons/in.^{2}, nitrided all over. The hardness conferred by such nitriding, and the resulting reduced wear is obvious, but a much more interesting point is that a greatly-increased fatigue resistance is thus obtained at the regions of stress concentration, such as oil holes, fillets, etc. The camshaft and rockers for an in-line engine should also be mentioned as components which must withstand very severe service. Case-hardened 5% nickel steels are used for the shaft and the rockers, the latter being covered with a thick deposit of chromium, representing an expensive but not entirely trouble-free combination. Turning to bearings, it may be said that, in general, lead bronze (on a steel backing) has almost entirely replaced white metal as the bearing material, but is only just able to meet the duty demanded ; the materials of the delicate floating bushes are a tin-base alloy containing Sb, Cu, Ag, and Ni in conjunction with a backing of a low-carbon steel containing silicon and manganese. A suitable material for gears has always been of primary importance to the aero engine, and particularly so with the airscrew and supercharger drive ; at present, the gear position is regarded as satisfactory, but the demands on this component continue to increase ; a typical material of to-day is a case-hardened Ni-Cr steel of 85 tons/in.^{2} tensile strength.

Turning to other outstanding engine components made of light alloy, we may recall the large cylinder block and crankcases, also various castings in cast aluminium alloy for the in-line engine, and the intricate forging, of the improved "Duralumin" type of alloy, used for the front and rear crankcases of a radial engine. Magnesium alloys already find many uses in some engines ; as an outstanding example mention may be made to the cast crankcase used in a leading in-line engine, where a Mg alloy containing 8½% Al, 3½% Zn is employed. For the special conditions in exhaust manifolds and silencers a special Ni-Cr-Fe alloy, having a high nickel content, is coming into use ; it is especially suitable because of its combination of strength, toughness and ductility coupled with resistance to heat and corrosive influences.

Landing Gear Components

A typical landing gear represents many interesting uses of ferrous and non-ferrous metals of which perhaps special mention may be made of the wide use of magnesium-rich alloys, containing aluminium and zinc, for such purposes, in the cast condition, as the wheel, control valves, undercarriage bracing members, etc., and in the forged condition, for those components subjected to hydraulic pressure. The development of "conducting" rubber for landing wheels must be regarded as a noteworthy achievement. Synthetic rubbers find in aircraft a use for piston cups and gland rings of the hydraulic units in which engine-driven pumps cause such a rise of temperature that natural rubber and other materials have proved to be quite unsuitable ; also, natural rubber is useless in contact with the non-freezing oils employed in this gear.

Metals and Alloys

The first impression gained from a survey of the metals and alloys available for aircraft purposes in 1938 is one of admiration for what has been accomplished, followed immediately by a realisation of the immense possibilities that remain for future research and development. Pure metals do not find much use for aircraft purposes, yet, as bases for practical alloys, their intrinsic properties are of fundamental interest ; strange as it may seem, it is only comparatively recently that any degree of success has been obtained in isolating a few metals in a high state of purity and determining their physical properties, thus making a first step in a fundamental aspect of scientific metallurgy.

In addition to future possibilities of radically new alloys, much development is likely to result by the improvement of existing alloys by relatively small alterations in composition, by suitable heat-treatment and by refinement of methods of manufacture. Taking the alloy steels again as an example, their strength, resistance to creep, and many other properties, depend largely on the distribution of the alloying elements between the iron and the carbon and on the arrangement of the carbide particles, while further work on the effects of small quantities of impurities, on such properties as temper brittleness and inter-crystalline attack is well worth while.

It is most probable that the future will disclose great developments that may amount almost to a revolution in metallurgy—i.e., the production of alloys by the sintering of powders. The method has great general possibilities of affording a small grain size, freedom from segregation, and "graded" properties : one can visualise—e.g., an engine liner having the required bearing properties at the surface, and, also, those "joining" properties so desirable at the junction to the steel or other backing material.

Steels

In addition to carbon—the essential element which modifies the properties of iron and converts it into steel—the most important alloying elements used in aircraft steels are nine in number—i.e., nickel, chromium, molybdenum, tungsten, vanadium, manganese, titanium, cobalt and silicon, of which the five first named are especially valuable. These aircraft steels are covered, at the time of writing, by no less than 90 specifications, relating to materials which vary widely in composition, mechanical and physical properties ; for summary purposes, they may, perhaps, be considered as falling into some three broad main groups and about 17 types, based on essential composition, as follows :

CARBON STEELS.

Mild steels (C > 0·35%).
Medium carbon steels (0·35/0·45% C).
Higher carbon steels (0·4/1·0% C).

LOW ALLOY STEELS.

Manganese steels (1½% Mn).
Nickel steels (3/5% Ni).
Nickel chromium steels with small additions (Ni 3/5%, Cr. 0·5/1·6%).
Chrome-molybdenum steels (Cr 0·5/3·5%, Mo 0·15/1·5%).
Chrome-vanadium steels (Cr 1·0/1·5%, Va > 0·25%).
Silico-manganese steels (Si 1·6/2·1%, Mn 0·8/1·3%).
Chrome-aluminium steels (Cr 1·4/1·8%, Al 0·9/1·3%).

HIGH ALLOY STEELS.

Special alloys steels (Ni > 1·0%, Cr 3½/14%, Va > 1%, W 14% +, Co 3/5%).
Manganese steels (Mn 11% +).
High chromium, low carbon (Cr 12 + %, C 0%/0·15%).
High chromium, medium carbon (Cr 12 + %, C 0·15/·35%).
High chromium, low nickel (Cr 16/20%, Ni 1/3%).
Austenitic chrome-nickel (Cr 12 + %, Ni 6 + %).
Austenitic chrome-nickel tungsten (Cr 12 + %, Ni 9 + %, W 0/6%).

Glancing over the present position in general, carbon steels are still employed with carbon content ranging from 0·05 to 0·85%. The low-carbon type has the advantage of being most readily welded and can also be easily fabricated into forms suitable for lightly-stressed parts.

Where a high fatigue strength allied with substantial ductility is required, this is achieved by the addition of special elements which facilitate the proper hardening of the steel and enable a uniform and homogeneous structure to be obtained on subsequent tempering. In this category of low alloy steels, we find the use of 3% or 5% of nickel with or without the addition of up to 1½% of chromium, or the addition of other elements such as molybdenum, vanadium or tungsten. The outstanding high tensile steel is one containing about 3% of nickel, 1·0% of chromium, molybdenum 0·5%, vanadium 0·2%.

Turning now to the more specialised steels in which the alloying metals are added in greater quantities, mention may be made of some of the outstanding materials. There is now available a large range of high chromium and chromium-nickel steels having specially high resistance to corrosion. The well-known rustless steels were based on a chromium content of 12-14%, in this series the carbon content varied from under 0·10%—in the case of steels of desired low tensile strength—up to 0·3-0·4% C, where, as a result of hardening and tempering a high tensile con-

dition is desired ; these steels are still used. A great impetus was given to the use of rustless steel when the austenitic type of material came along, in which a substantial proportion of nickel, eight to 10% is used in conjunction with a chromium content of the order of 17–20%. Such steels, together with some of intermediate composition, provide all that is necessary for the construction of parts subjected to corrosive conditions ; small additions of titanium, molybdenum, etc., prevent intercrystalline attack. An allied class of steels is that used for exhaust valves, but here it is found that the addition of tungsten to the high chromium-nickel content is an advantage, together with an increase in carbon content. Such materials exhibit a high resistance to oxidation and scaling, also, a greatly enhanced strength at the high operating temperatures.

As one very interesting instance in the development of materials for aircraft, mention may be made of the need, for valve inserts, of a steel having a coefficient of expansion approximating to that of the aluminium alloys. Investigation showed that a steel containing about 12% of nickel, 3–4% of chromium and about 5% of manganese, had a suitable coefficient of expansion 0·000022 ; it was immediately and successfully adopted for the required purpose. This is one of those instances where the requirements of design, when properly expressed, receive an adequate and immediate answer from the metallurgist. It is understood that a steel has now been produced having a coefficient of expansion as high as 0·000029 ; suggestions for engineering applications of this steel are awaited by the producers.

Metallurgical research has been responsible for the introduction of steels which are magnetic or non-magnetic as desired, which are rustless, and which have a most surprising degree of hardness. Clearly, the future of steel, in competition with other metals for aircraft purposes, will be determined by the properties which can be progressively induced in the future, but the record of the past gives substantial indication that marked further progress may be expected.

Alloys of the Light Metals

The essential requirements of aircraft construction have led to intensive studies of the alloys of the light metals. Metals of the alkali and alkaline earths are chemically far too reactive to be used for constructional purposes, leaving for practical consideration only three metals, aluminium, magnesium and beryllium, having densities of 2·7, 1·74 and 1·83, respectively. Beryllium, once considered so full of promise has proved extremely disappointing, in spite of extensive research ; industrial alloys are practically limited to copper-rich and nickel-rich alloys containing only about 3% of Beryllium, and cannot therefore be classed as light alloys. At the present time, therefore, we are left with alloys of aluminium and magnesium.

Aluminium Alloys

The use of aluminium in the comparatively pure state is of fairly long standing. It possesses high resistance to corrosion, when in a high degree of purity ; an unexpected property which was only accounted for when the nature of, and protection afforded by, thin oxide films were discovered. Pure aluminium has only a low mechanical strength, even after cold rolling and its most extensive present aircraft use is a covering for composite sheet where it finds most valuable applications. There are three ways in which a soft metal, such as aluminium, may be made stronger by alloying. The added element may enter into solid solution, or it may give rise to a second phase which, suitably distributed through the metal, forms a rigid skeleton, or it may allow the precipitation of ultra microscopic particles in the course of heat-treatment, producing "age hardening." The first of these methods has little application to aluminium, owing to the small range of solid solutions ; the second kind of hardening is found in the casting alloys, while the third is the most important. The most valuable alloying systems are as follows :

Al-Cu (Cu up to 9%).
Al-Cu-Mg (Cu 4%, Mg up to 2%).
Al-Cu-Mg-Si (Cu 4%, Mg 2%, Si 1·5%).
Al-Cu-Mi (Cu 4%, Ni 2%, with addition of Mg and Si).
Al-Mg (Mg 5/10%, with additions of Mn, and Sb).
Al-Mn (Mn up to 2%).
Al-Si (Si 8/13% with additions of Mg, Mn or Co).

It is well known that the precipitation at room temperatures and at elevated temperatures of a dissolved constituent causes marked hardening in the properties of many aluminium alloys. Since Wilm's time many alloys, other than the original duralumin, have been developed, and these alloys may be considered in the three classes of (1) heat-treatable alloys containing copper and magnesium (2) heat-treatable alloys not containing copper, and (3) non-heat-treatable alloys under the main groupings of wrought and cast alloys.

It will be appreciated that the "texture" of the alloy has a great influence on the heat-treatment reaction in that wrought alloys have a much greater reactivity than cast alloys, the consequence being that heat-treatment times for cast alloys are considerably longer than those which apply for wrought alloys.

A word may be said here about the corrosion resistance of the heat-treatable wrought alloys. In general, those alloys which are aged at room temperatures have a fairly high resistance to corrosion, but those alloys which have been precipitated are susceptible to intercrystalline corrosion. Of these alloys those of the type not containing copper, are by far the most resistant. Adequate protection, however, renders these alloys quite serviceable in aircraft manufacture.

The value of copper and zinc as hardeners for aluminium casting alloys has been recognised from the early days of the industry. Straight zinc alloys are very rarely used nowadays, however, mainly because they tend to crack in the mould owing to hot shortness. Considerable improvement was recorded by adding to such alloys a quantity of copper, and of this type of alloy, that containing about 13½% of zinc with 2½% of copper is by far the most popular.

The alloys of aluminium and silicon are particularly interesting and have a very considerable use nowadays. An alloy containing about 13% of silicon when subjected to the process known as modification, which consists in treating the melt before casting with metallic sodium or a suitable salt of sodium undergoes a considerable improvement in its properties as a result of the refinement of the structure. The mechanical strength of these modified alloys is high, and this strength is accompanied by a large measure of elongation. Unfortunately, the elastic limit, in spite of the high strength is no higher than that of the other common casting alloys, the metal is soft and is not easily machined. The alloy, however, has a very high resistance to corrosion, and has found use for service on ships and for parts of chemical plant. From the casting point of view the alloy is particularly easy to handle. It is extremely fluid, and has a very low contraction of solidification so that it may be cast into forms which have very thin sections.

A more recent development of this alloy consists in the addition of a small quantity of magnesium, which makes the alloy heat-treatable ; in different heat-treated conditions it is called Silumin Beta and Silumin Gamma. The first name is applied to the solution-treated condition, quenched from 520° C. at room temperature ; the second to the precipitated condition, quenched from 520° C., and aged for 20 hours at 175° C.

By far the best known of the heat-treatable cast alloys of aluminium is "Y" alloy, which contains 4% of copper, 2% of nickel, and 1½% of magnesium. In the cast condition, this alloy has not any remarkable properties, but after heat-treatment a considerable increase in strength is obtained.

A most important series of casting alloys of aluminium known as the RR alloys has been introduced for aircraft purposes during the last eight years. The comprehensive composition of the whole series is : Cu 0·5–5%,

Ni 0·2–1·5%, Mg 0·1–5%, Fe 0·6–1·5%, Ti up to 0·5%, and Si 0·2–5%. They are in very extensive use and probably yield the majority of aircraft castings.

For RR 53 a double heat-treatment is specified : Solution heat-treatment of heating at 510–535° C. for two to four hours, and quenching in water ; precipitation heat-treatment of heating at 155–175° C. for 20 hours, and quenching in water. For RR 50 no solution heat-treatment is specified : After cooling from the mould, the alloys are given a precipitation treatment by heating at 155–175° C. for eight to 20 hours followed by quenching in water. The minimum properties obtained from these alloys are :

	0·1 Proof Stress.	U.T.S.	Elong. %	B.H.N.
RR 53	19 tons/in.²	20 tons/in.²	1	106/140
RR 50	8 tons/in.²	13 tons/in.²	4	59/80

Magnesium Alloys

In the very earliest production of magnesium alloys, entrapped flux and the highly reactive nature of the metal, were responsible for many disappointments. Modern production has eliminated many of the problems in casting, although their quality still leaves much to be desired ; however, magnesium-alloy castings of high purity and a fair degree of soundness are now finding widening applications.

Magnesium is too weak a metal to be used in the unalloyed state, and the metals which may be added to it to produce strong alloys are very limited in number. Magnesium alloys, containing Al and Zn as essential constituents, were first developed in Germany, during the period 1908–1920, under the name of "Elektron," still used as the trade name for alloys made under licence. The possibilities of added alloying elements are still being vigorously pursued ; the binary alloys, other than that with Al do not, as yet, offer great advantages, and the ternary systems are being studied systematically. The following systems have been investigated to some extent with various degrees of success :

Mg-Mn (Mn 2½% max.).
Mg-Al (Al 8/12%).
Mg-Ce (Ce 10%, with or without additions of Co. and Mn).
Mg-Al-Ag (Al 7½/8½%, Ag 2½/3%, with additions of Zn Mg and Ca).
Mg-Al-Zn (Al up to 11%, Zn up to 3½%).
Mg-Al-Cd (Al 8%, Cd 8%).
Mg-Cd (Cd up to 20%).
Mg-Cd-Zn (Cd 4%, Zn 4%).

Magnesium alloys present difficulties in working processes, arising from the hexagonal crystal structure, tending to produce marked directional properties ; the structure easily twins, however, and this has led to special processes of manufacture where by repeatedly changing the direction of stress, the structure can be broken down—affording increased general ductility. Two factors have tended to retard the development of magnesium alloys for aircraft and other purposes, inflammability and low resistance to corrosion both intrinsic disadvantages of magnesium. But opinion appears to be divided on the increased fire risks attached to the use of magnesium alloys in aircraft. Where thick sections are employed the fire risk may be considered as negligible ; this is borne out by actual engine experience, and there is little doubt that the fire risk has been over-emphasised in the past. Magnesium alloys must be regarded as readily corrodible. No addition of an alloying metal, in reasonable quantities has yet been found to inhibit corrosion, although the addition of small quantities of manganese is known to be favourable. But the resistance to corrosion is actually greater than might be expected. Methods of protection by forming an adherent protective layer, united chemically to the metal have been devised.

Magnesium Alloy Castings

Large and highly complex sand castings can be made in magnesium alloys with greater difficulty than attends the production of similar castings in aluminium alloys. Gravity die-castings are being successfully produced, but the existing dies for aluminium alloys require some modification. This latter condition applies also to pressure die castings, numerous forms of which are now in production. The advantages claimed for the magnesium alloys are : (1) 40% weight reduction compared with aluminium, (2) freedom from embrittlement in service, (3) absence of pinholing, (4) simplified design in the elimination of cored holes and pockets without appreciable increase in weight, and (5) achievement of stiffness with low weight. Numerous specifications for magnesium alloys cover a wide range of compositions and properties. The general composition of this group of casting alloys is covered by the following limits : Al 0·2–11 max., Zn 0·2–3·5 max., Mn 0·5–2·5 max. Two methods of treatment are available, a solution heat-treatment, usually consisting of heating at 420° C. for 24 hours (during this treatment, the metal is protected either by using an SO^2 atmosphere or employing a dichromate salt bath) or, alternatively, a precipitation-hardening treatment of from 12 to 48 hours at 150–200° C. ; some of the alloys are used in the "as cast" condition. Within this group, the derived properties vary widely with composition ; it must suffice to quote two essentially different types. The first has a maximum composition of 8·5% Al, 3·5% Zn, and 0·5% Mn ; castings of this alloy are used either in the "as cast" condition or after solution heat-treatment ; the maximum composition of the second alloy is 0·2% Al, 0·2% Zn, 2·5% Mn. ; it is used only in the cast condition. The mechanical properties of these alloys are :

	0·1% Proof Stress.	U.T.S.	Elong. %
One sand cast	4½/5½ tons/in.²	9/11 tons/in.²	3/5
Sand cast and S.H.T. ..	4½/5½ tons/in.²	14/16 tons/in.²	9/14
Two sand casts	1½ tons/in.²	6/7 tons/in.²	3/5

The first type is the typical product of this general group of magnesium alloys ; the second is used for lightly stressed parts, and is easily welded.

Wrought Magnesium Alloys

These alloys lend themselves without serious difficulty to extrusion, rolling and forging, and are thus available in all the usual wrought forms and most of the sizes in which the wrought aluminium alloys are obtainable ; magnesium alloys, however, cannot be cold-worked.

The Mg-Mn group yields an alloy notable for weldability ; as it also possesses superior workability and corrosion resistance, it provides the sheet alloy largely used for the fabrication of fuel and oil tanks, containers, panelling, etc. It has a maximum content of 2·5% Mn with small additions of Al (0·2%) and Zn (0·2%). It exhibits a 0·1% proof stress of 6–8 tons/in², an U.T.S. of 12–15 tons/in.², and an elongation of 7–10%.

The Mg-Al alloys are used for structural purposes and stressed parts, and supplied mainly in the form of extrusions, also sheet and forgings. The general composition of the group is covered by the maximum composition limits of 7·5–11% Al 1·5–2% Zn and 1% Mn. As typical examples we may select three alloys which find extensive use for (*a*) sheet, (*b*) bars and extrusions, (*c*) crankcase and airscrew forgings ; their compositions and tensile properties are as follows :

	Al (max.).	Zn (max.).	Mn (max.).	0·1% proof. Stress t./in.²	U.T.S. t/in.²	Elong. %
A	9	1·5	1·0	7	16	10
B	11	1·5	1·0	9/11	14/17	5/10
C	11	2·0	1·0	10/12	17	5

As magnesium alloys present certain peculiar difficulties in certain directions, a brief note may be added on these aspects. With regard to bending, shaping, deep-drawing and similar operations, the difficulties of cold-working must be accepted and advantage taken of the ease with which the alloys may be worked at temperatures around 300° C. ; further, for all deformation processes, especially deep-drawing, the slower the speed, the better the result. Several of the wrought alloys and castings may be successfully welded by the oxy-acetylene process using appropriate welding rods and fluxes ; the welding flux, however, is

highly corrosive and must be most carefully removed from the welds, by washing, brushing and chromating. With regard to the machining aspect, the use of a high-cutting speed is to be advocated, using very sharp tools and fairly heavy cuts. Danger of fire is small when the chips are reasonably heavy, but when using an insufficiently-coarse-cut and a blunt tool, it is possible locally to heat to above the melting point, and so produce a "swarf" fire. For riveted construction, rivets of an aluminium alloy containing 5% Mg are recommended by the makers. The intrinsic low resistance to corrosion of Mg alloys is still a great disadvantage, and greatly restricts their applications to exposed parts. Chromating solutions are used as a basis for paint and enamel finishes; the two types most commonly employed are the dichromate short-time immersion, giving a golden-yellow film, but producing a wastage of the alloy that cannot be permitted in certain cases also the "R A E baths" (30 minutes and six hours) which, producing a black finish on Mg Al alloys, and a brown finish on Mg-Mn alloys, only result in negligible wastage. But the broad position is that although the coatings described are good enough for ordinary purposes, they are markedly inferior to the anodic oxidation as applied to aluminium alloys; for sea-water corrosion, there has not yet been developed any reliable corrosion-resisting treatment for alloys of magnesium, so that the existing coatings can only be described as palliatives, not good enough for some of the exacting conditions of modern aircraft.

In the above survey, attention has been confined to commercially available alloys of magnesium. But considerable research has been made at the National Physical Laboratory in recent years into alloys containing cerium, nickel, cobalt, manganese, silver and calcium and, while the practical applications of these alloys is still largely in the experimental stage, there is reason to hope that useful practical applications to aircraft construction will emerge.

Copper at Elevated Temperatures

IN an investigation on copper for ingot moulds and stools for the United States Metals Refining Co., an opportunity was afforded to determine the mechanical properties of copper at elevated temperatures in order to determine what type of copper would be best suited for the purpose in view. Such an investigation was carried out by Lorig, Dahle, and Roberts,* who determined the tensile and impact test of cast and hot-worked copper over a temperature range from 95° to 700° C.

Three types of copper, oxygen free, high-conductivity; phosphorised oxygen-free high-conductivity; and tough pitch were received in cast blocks cut from the centre of 400 lb. cast ingots. Tensile tests were taken 1 in. from either side of the blocks so that the crystals of the specimens were normal to the longitudinal axis, while impact tests were cut so that the Charpy key-hole notch was normal to the columnar crystals extending in from the side of the ingot. Sections 4-in. square were cut from the cast blocks and hot-forged to 1¼ in. square rods which were then rolled to ¾ in. rounds. The forging and rolling of the bars were carried out at 650° C. and the bars were tempered at 315° C.

The tensile tests at elevated temperatures on both cast and worked specimens were made in accordance with the A.S.T.M.-A.S.M.E. Joint High-Temperature Committee Standards. Owing to the high conductivity of copper, the specimens were only maintained at the testing temperature for ½ hour instead of 1 hour. Tests were made at 11 temperatures over the range 95° to 700° C. two tests being made at each temperature. Three Charpy impact specimens were tested at similar temperatures, the test pieces being heated to the test temperature and then removed rapidly from the furnace, which was placed just opposite the anvil of an Amsler impact machine, and broken.

Some of the results obtained in testing the as-cast bars are given in Table I.

TABLE I.
TENSILE DATA ON CAST COPPER.

Test Temperature ° C.	Max. Stress Tons per sq. in.	Elong. %	Red. of Area %	Charpy Impact ft. lb.
Oxygen-Free High-Conductivity Copper—				
95°	9·7	54·7	80·8	35·8
370°	4·6	19·0	17·8	29·8
700°	1·4	38·5	36·2	19·8
Phosphorised Oxygen-Free High-Conductivity Copper—				
95°	10·0	49·3	85·5	35·7
370°	5·6	44·0	85·0	30·8
700°	1·8	70·2	98·9	19·7
Tough-Pitch Copper—				
95°	10·2	27·5	30·0	8·7
370°	. 3·9	8·3	10·3	9·3
700°	1·1	8·0	12·0	8·7

* *Metals and Alloys*, 1938, vol. 9, No. 3, pp. 63 to 67.

There was no great difference in the strengths of the various coppers, all three showing a falling-off with increase in temperature, although the phosphorised copper was a little better at higher temperatures. The tendency for the strength to decrease slowly and uniformly with temperature was unexpected in view of the trend of tensile strength-temperature curves recorded for annealed wrought copper and for other metals. The impact tests showed oxygen-free and phosphorised copper to have reduced values at 205° C. with an increase at 315° C., after which they gradually fell off. The tough-pitch copper showed very little change in impact strength over the whole range, the values obtained, however, being low.

Data for some of the results obtained on the hot-worked and tempered coppers are given in Table II.

TABLE II.
TENSILE DATA ON HOT-WORKED COPPER.

Test Temperature ° C.	Max. Stress Tons per sq. in.	Elong. %	Red. of Area %	Charpy Impact ft. lb.
Oxygen-Free High-Conductivity Copper—				
95°	15·4	58·8	87·1	45·5
425°	6·9	80·8	95·3	40·8
700°	1·5	100·5	99·0	23·3
Phosphorised Oxygen-Free High-Conductivity Copper—				
95°	14·5	59·0	87·2	45·5
425°	6·15	36·8	35·4	44·1
700°	1·65	66·5	95·7	25·5
Tough-Pitch Copper—				
95°	14·6	60·0	72·7	34·1
425°	5·85	59·3	46·8	39·0
700°	1·95	54·5	92·0	24·8

No great differences were observed in the tensile strengths of the hot-work coppers and again a uniform falling off in strength with increase in temperature was obtained. All the hot-worked coppers showed some embrittlement in the temperature range from 120° to 230° C., but recovered their impact strength at 345° C., after which the impact strength fell off gradually with increase in temperature. Both the oxygen-free copper and the phosphorised copper have slightly higher impact values than the tough-pitch copper up to 425° C., but above that temperature the impact strengths are about the same.

In general, in the as-cast condition, the phosphorised copper was slightly superior to the other types of copper in tensile strength at elevated temperature and was more ductile. After hot-working and tempering, the oxygen-free copper was uniformly ductile at all temperatures, whereas the phosphorised and tough-pitch copper showed marked decreased ductility from 175° to 540° C. The tensile strength of as-cast and of annealed wrought copper decreased uniformly from room temperature to 700° C. while the impact strengths of the oxygen-free and the phosphorised copper were superior to the impact strengths of tough-pitch copper.

Comparative Effects of Controlled Atmospheres

The results are given of an investigation which had for its object the determination of the difference in behaviour of some alloy and plain carbon steel towards various controlled atmospheres.

THE successful use of cheap, partly-burned gases as protective atmospheres for the heat-treatment of plain low-carbon steels has led to a demand for similar atmospheres for high-carbon and special alloy steels. That the requirements for such atmospheres are far more exacting than when heat-treating plain low-carbon steels has long been recognised by metallurgists and others concerned with these problems. Highly-alloyed steels may depart considerably from the behaviour of plain carbon steels, both as regards scaling and decarburisation, but how marked these effects may be on the moderately-alloyed steels, which form the bulk of heat-treated products, is a matter that can only be settled by experiment, and experiments of such a nature have been made by E. Slowter and B. W. Gonser, with a view to determining how far some of the important alloy steels and plain carbon steels differ in their behaviour towards various controlled atmospheres.

In previous investigation* the effects of various atmospheres on plain carbon steels of 0·07 to 1·02% carbon were determined, and certain conclusions drawn for the bright-hardening of plain, medium, and high-carbon steels without scaling or decarburisation. In the present investigation two types of atmospheres were dealt with, six synthetically prepared, and three of partly-burned natural gas. The former types included pure nitrogen; 5% carbon dioxide with balance nitrogen; 5% carbon dioxide with 0·3% methane and balance nitrogen; 10% hydrogen with balance nitrogen; 10% hydrogen with 2% methane and balance nitrogen; and a mixture of 9% carbon monoxide, 10% hydrogen, 1% methane, 80% nitrogen; while the latter type were undried generator gas, dried generator gas, and dried carbon dioxide-free generator gas. The synthetic gases were prepared in a similar manner to those used in the previous experiments.

Four plain carbon and 20 alloy steels were used in the investigation, the alloy steels included nickel, chromium, molybdenum, nickel-chromium, 18/8, high-speed tool, nitriding, copper-content, etc. The samples of these steels, which were prepared as formerly, were separated into three temperature groups (800°, 900°, and 950° C.), each sample being placed into that group whose temperature most nearly corresponded with the ordinary heat-treating temperatures for that particular steel. A plain carbon steel in each group served to correlate results with the alloy steels and the previous work on plain carbon steels. The procedure adopted for testing was as in former experiments, and a three-hour period of exposure at each temperature was selected so as to exaggerate and emphasise any weight changes that were taking place.

Pure nitrogen was selected as an atmosphere because it offered a base-line for comparison being just faintly on the decarburising side and gave slight traces of temper colours. Dilute carbon-monoxide-nitrogen atmosphere has a very slight decarburising action, but prevented the formation of temper colours because of the presence of carbon monoxide. This latter gas, however, formed an unoxidised film over chromium steel. The faint decarburising action of this mixture was eliminated by a slight addition of methane. A dilute hydrogen-nitrogen atmosphere was just slightly more decarburising to all of the steels than pure nitrogen, though the prevention of temper colours are easier, and its action was about the same for all alloys, being somewhat greater as the carbon content increased. The addition of a small amount of methane caused it to have a carburising effect. A dilute carbon-monoxide-hydrogen-nitrogen atmosphere with about 1% of methane was carburising to all of the steels.

The undried generator gas was decarburising to all steels, except those of quite low carbon contents, even at 800° C. At this temperature alloy steels appeared more resistant than plain carbon steels, but at higher temperatures this difference was not apparent. Dried generator gas was very similar in action except at 800° C., where its decarburising effect was materially lessened, while in dried carbon dioxide-free generator gas decarburisation is eliminated because of the absence of the carbon monoxide, and it behaved similar to the synthetic mixture of carbon monoxide, hydrogen, nitrogen, and methane.

In general with regard to the atmospheres which may be used on a wide variety of alloy steels, it may be said that carbon dioxide and water are just as detrimental to medium- and high-carbon alloy steels as to plain, medium and high carbon steels and their complete removal from a heat-treating atmosphere is desirable for the same reasons. Dried, partly-combusted gases are just as severe in their action on carbon and alloy steels at temperatures over 880° C. as the undried gas, but are somewhat milder in their action at lower temperatures. Any atmosphere, with a few exceptions, which is suitable for a range of carbon steels is also suitable for a similar range of alloy steels of the same carbon contents.

As regards steels, it was found that in general the behaviour of the various alloy steels was practically dependent upon the carbon content of the steel in much the same manner as plain carbon steels. At 800° C. the various alloys steels exhibited slightly better resistance to change, either carburisation or decarburisation than the plain carbon steels, and this was not noticeable at 800° and 950° C. The high chromium steels behaved quite different from the other alloy steels, except the silicon steels, which also showed slight abnormalities.

From the investigation it was concluded that the majority of alloy steels behave in approximately the same manner as plain carbon steels of the same carbon content, the alloy steels often being slightly more resistant to change especially at the lower temperatures. Both high and low chromium steels are especially susceptible to oxygen-containing gases, extreme care in the removal of the latter being necessary if prevention of oxidation is desired, as even carbon monoxide may give up its oxygen to chromium-bearing alloys. Steels containing relatively large amounts of silicon are more resistant to change, either carburisation or decarburisation, than plain carbon steels of equal carbon content. Nickel steels are slightly more resistant to filming during heat-treatment than ordinary carbon steels, while low chromium steels are much less resistant. Films do not materially affect the rate of either carburisation or decarburisation, so that from the point of view of hardening rather than of appearance, they should not influence the choice of atmosphere.

The investigations have a bearing on the behaviour of resistors, furnace parts, etc., fabricated of high-chromium heat-resisting alloys where an oxide form of suitable properties may be protective while one of other properties may be deleterious. The effect of atmosphere upon the furnace, also, cannot be neglected and form another phase of a general investigation upon which work is now in progress.

* *Metals and Alloys*, 1938, vol. 9, No. 2, pp. 33 to 39; and No. 3, pp. 59 to 62.

Some Fundamental Factors Regarding the Stress-Strain Diagram of Mild Steel

By G. WELTER and S. GOCKOWSKI

A series of tests are described which show the influence exerted by the design of testing machines in the development of stress-strain diagrams. It is shown that the drop in stress at the yield-point of mild steel is due to the reaction of the indicating grip holder upon the indicated load and it is suggested that views on the nature of upper and lower yield-point should be re-examined.

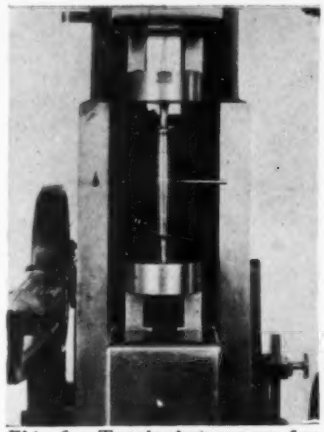


Fig. 1.—Tensioning screw for determining the reaction of the grip head upon the dynamometer.

IN connection with the question of the true course of the stress-strain diagram of mild steel in tensile tests, a series of trials was carried out in an effort to clarify previous results. In addition to test results already available, a few fundamental investigations were made. In the first instance, the influence of the inherent resilience in the machine upon the modification of the stress-strain diagram recorded by the tensile machine was investigated by reproducing the variation in the length of a test-piece under tensile stress, by clamping a machine component capable of being regulated in longitudinal direction. In connection with this, inherent resiliency of six different types of machines were checked and the stress-strain diagrams obtained on these machines for mild steel were subjected to comparative examination. In order to advance closer to the true course of the stress-strain diagram, it was considered of interest to ascertain, on the basis of comparative tests carried out up to the present with soft and hard resiliency of the equipment, at what load the yield-point of mild steel starts in machines of considerable natural spring compared with machines with hard inherent resilience with the known drop in stress at the yield-point. A clarification of the question whether in tensile tests with soft springing the material starts to flow from the upper or lower yield-point should contribute materially towards the knowledge of the theoretical stress-strain diagram.

Performance and Results of Tests

(*a*) *Stress-elongation Diagram for Given Increase in Length.*—In order to reproduce the increase in the length of a test-piece, subject to the tensile test, in a chronologically measurable manner, a tensioning screw (double nut with right- and left-hand thread) as in Fig. 1 was fitted in the clamping heads of the machine (5-ton Amsler machine 5ZD 181), and in the course of loading the length between the clamping heads was varied by turning the shackle nut, a revolution of which caused an increase in length between the clamping heads of approximately 0·6 mm. Increasing the load on the machine with a slow and gradual rotation of the nut at a load stage of approximately 300 kilogs. (equivalent to a yield-point of mild steel of approximately 3·5 mm. diameter) recorded the diagram *a* from a machine with usual springing as in Fig. 2. The characteristic drop in load shown occurred regularly with machines of the usual type, although the nut was turned slowly and evenly without initial acceleration.

According to the motion of the nut, the variation in length, and consequently the elongation at the yield-point, could be increased. The rise of load in the diagram was not perpendicular to the axis of the abscissæ, because in order to reproduce the originally small elongation of the material thin rubber underlays were provided between the clamping jaws in this test. The velocity of motion of the lower clamping head in these tests was approximately 0·1 mm. per second. This method afforded a simple way of reproducing the yield of mild steel at the yield limit, and its influence upon the stress-strain diagram as often as desired, and to subject it to accurate examination.

If either a soft helical spring (approximately 23 mm. per 100 kilogs. load) or the hydraulic-pneumatic apparatus be incorporated between the lower clamping head, and the loading spindle and the tests repeated with the tensioning screw under the same test conditions, the diagram *b*, as in Fig. 2, will be recorded by the machine. This diagram does not show any stress drop from an upper to a lower yield-point when operating the screw, as in the first case. On the contrary, the steeply rising curve passes in the short bend over into a branch rising at a flatter rate. The test velocity within the yield area amounted to approximately 0·05 mm. per second. The diagram *b*, Fig. 2, corresponds with the characteristic diagrams published in earlier work, which were obtained on soft-sprung machines. The tests, which may be readily reproduced on any machine and repeated *ad libitum* indicates that the springing of the equipment exerts vital influence on the formation of the stress-strain diagram at the yield-point of mild steel.

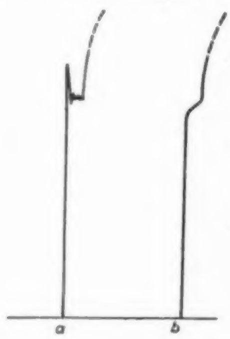


Fig. 2.—Reaction of the indicating clamping head :
(a) In hard-sprung machines. (b) In soft-sprung machines.

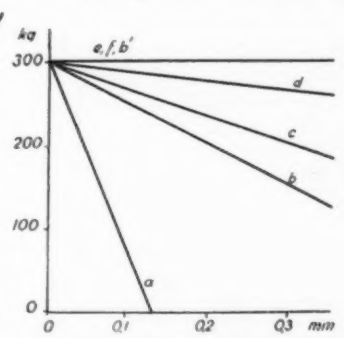


Fig. 3.—Reaction of the indicating grip holder upon the load indicated : (a) 20-ton Amsler machine. (b) 5-ton Amsler machine. (c) 50-ton Mohr and Federhaff machine. (d) 3-ton Amsler machine. (e) 4-ton Amsler machine. (f) 300-kilog. Amsler machine. (b') 5-ton Amsler machine with helical spring.

According to the pitch of the thread of the tensioning shackle and the way the nut is operated by means of worm-gear, the process may be repeated at the yield-point of mild steel with fair accuracy.

(*b*) *Different Types of Machine : Their Stress-elongation Diagrams.*—In connection with the foregoing tests, the ratios of transmission, between load indicator and the drop in stress, on the increase of length between the clamping heads of various types of tensile test machines, were

subjected to accurate checking. The tests were carried out by determining the ratios of transmission of six different types of tensile machines by means of the tensioning shackle described, which was inserted between the clamping heads—viz., by determining the increase in length between the clamping heads as a function of the drop in tension indicated by the dynamometer. In Fig. 3 this function

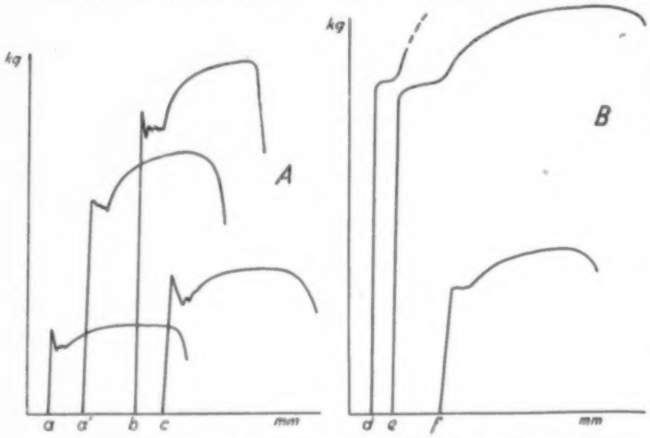


Fig. 4.—Stress-strain diagram of different tensile machines. A—Hard-sprung machines. B—Soft-sprung machines. (a and a') 20-ton machine. (b) 5-ton machine. (c) 50-ton machine. (d) 4-ton machine. (e) 300-kilog. machine. (f) 3-ton machine.

of dynamometer reading in kilogrammes is reproduced against the increase in length in millimetres between the clamping heads of six different types of machines. The maximum load manner of drive and also of the measurement of force in these machines are compiled in Table I, while in Fig. 4 A–B represent the stress-strain diagrams secured on these machines for mild steel.

In Figs. 5–10 the springing conditions and the actual machine design are also reproduced against the particular diagrams recorded by these machines.

TABLE I.

No.	Machine.	Drive.	Dynamometer.
1	20-ton	Hydraulic	Pendulum (hydraulic-mechanical)
2	5 ,,	Mechanical	Pendulum (mechanical)
3	50 ,,	Hydraulic	Pendulum (mechanical)
4	3 ,,	Hydraulic	Helical spring (mechanical-hydraulic)
5	4 ,,	Hydraulic	Helical spring (mechanical-hydraulic)
6	300 kilogs.	Mechanical	Pendulum (mechanical)

It will be noted that there are fundamental differences between the ratios of transmission of the various types of machines. Thus, for example, the hydraulic 20-ton Amsler machine (No. 1, Table I) with pendulum dynamometer shows quite an appreciable drop of force against minor increases in length between the clamping heads. In the load range of 300 kilogs. an increment of but 0·1 mm. causes a load drop on the dynamometer of more than 200 kilogs. (*a*, Fig. 3). This great drop in load is greatly reduced in the practical test by means of the damping incorporated in the hydraulic pendulum device (hydraulic brake). Furthermore, an increase in length of 0·1 mm. in the 5-ton Amsler machine with mechanical pendulum dynamometer and the 50-ton hydraulic Mohr and Federhaff machine (Nos. 2 and 3, Table I. ; *b* and *c*, Fig. 3) causes a drop in load of approximately 40 to 50 kilogs.—approximately one-sixth of the maximum load. In contrast to this, the machines for small maximum loads—viz., the 4-ton, 3-ton, and 300 kilogs. Amsler machines (Nos. 4 to 6, Table I.) only show a very minute drop in load against increases in length between the clamping heads, even up to 0·3 mm. (*d*—e.g., Fig. 3 ; 3-ton Amsler, limit area *d*). Also the 5-ton Amsler machine with the usual springing, according to *b*, Fig. 3, falls within the sphere of machines without load drop after interposing a helical spring or the hydraulic-pneumatic appliance. For the machine thus modified the load-drop distance diagram b^1 coincides with that of the machines *e*, *f*, Fig. 3.

TABLE II.

No.	Machine Tons.	Maximum Dynamometer Load. Kg	Diameter of Test-Pieces. mm.	Stress Drop.	Designated in Fig. 4.	Fig. No.
1	20	2,000	3·5 6	Present	*a* a^1	7
2	5	500	3·5	Present	*b*	5
3	50	10,000	10	Present	*c*	6
4	4	400	3·5	Absent	*d*	9
5	0·3	500	3·5	Absent	*e*	8
6	3	1,000	3·5	Absent	*f*	10

If mild steel test-pieces of 3·5 to 10 mm. diameter are tried on these machines according to Table II, with the load range as indicated, the original diagrams reproduced in Fig. 4 A, B, as recorded by the various machines. Here again it is perfectly obvious that the stress-elongation diagram of the machines 1–3, Table II (Fig. 3, *a*, *b*, *c*) with appreciable load drop, against increases in length between the clamping heads, show a very distinct upper and lower yield-point for mild steel, with a sudden drop in strain from the upper to the lower limit (Fig. 4 A). Similarly,

Fig. 5.—5-ton Amsler machine.

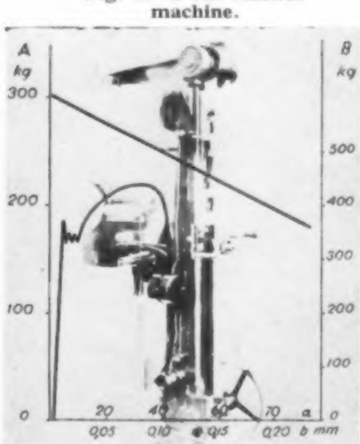


Fig. 6.—50-ton Mohr and Federhaff Machine.

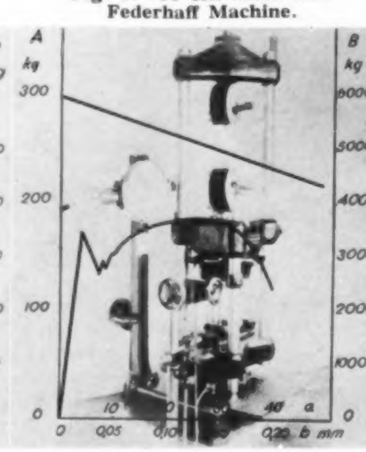
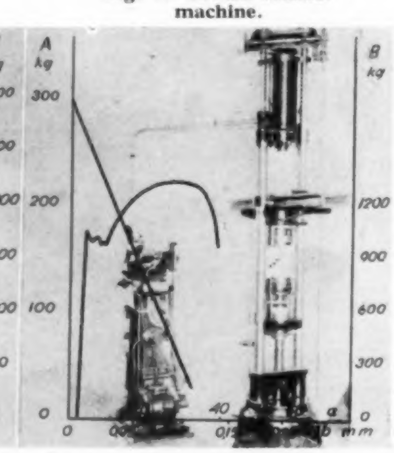


Fig. 7.—20-ton Amsler machine.



Figs. 5—10.—Stress-elongation diagrams : Function of motion of the indicating

the breaking load of all the test-pieces is appreciably lower than the lower yield limit.

Fundamentally different diagrams will be obtained by carrying out tests on the same material in machines Nos. 4 to 6 (Table II), with the springing indicated in Fig. 3, *d, e, f*. The original diagrams recorded by these machines and reproduced in Fig. 4 B, do not show drop in load near the yield limit. On the contrary, the loads in the range of the yield-point run practically parallel to the abscissæ axis, though gradually rising. Moreover, this range is passed quietly without the usual load jumps at an elongation speed of about 0·1% per second (test duration adopted several minutes). In a correspondingly longer test period the elongation velocity with the yield range is similarly reduced. This point is of especial interest, since it is frequently assumed that the yield-point is passed quite suddenly in this manner of loading. With these diagrams, moreover, the load-drop, until breakage of the tests, is appreciably less than with the diagrams shown in Fig. 4 A. In Figs. 5–10 these results are compiled in clear arrangement.

This comparison demonstrates that the drop of load in the range of the yield-point is solely contingent upon the type of the tensile machine and its springing between clamping head and force indicator, and not to any peculiar quality of the material. The drop in stress is thus absent, as has already been shown by a series of other tests, even on standard testing machines used in the usual way for tensile tests, providing the ratio of transmission between load and motion of the indicating clamping head is small. With machines for small maximum loads, which are frequently based upon a plain leverage, the stress-strain diagram produced adopts a perfectly steady and smooth course under gradually rising load in the range of the yield-point as do a number of standard machines.

(*c*) *Position of the Yield Limit with Soft-sprung Machines.*—Further to these test results, it was also a matter of special interest to determine at what load the yield limit starts with soft-sprung machines as compared with hard-sprung machines. Up to the present it has been altogether vague, whether yielding with soft springing, as is assumed, for example, by Pomp and Krisch[2] and by Siebel and Schwaiger,[3] starts at the upper yield limit and suddenly traverses the entire yield range due to appreciable excess of energy.

In contrast to this there is the possibility that in soft springing the upper yield-point is absent and that the stress-strain diagram enters directly into the yield range, which corresponds to the lower yield-point. In this case there is no surplus of work, and the test-piece will be elongated in the yield range perfectly steadily without fluctuations of load. In order to approach this fundamental question more closely, all the values relating to the yield limit have been compiled against one another with reference to the comparative tests so far carried out with hard and soft springing.

Table III gives a comparative compilation of the yield-points of mild steel tests of the same material which were obtained with soft-sprung machines (hydraulic-pneumatic appliance, or helical spring), compared with the values determined as the lower yield limit by hard-sprung machines. The upper yield limit which in all cases was approximately 2 to 5 kilogs. per sq. mm. above the lower yield limit with hard-sprung machines, has here been left out of account. As will be evident from Table III, the comparison covers the tests of 3·5 to 9 mm. diameter, which on the average of 14 individual results show a yield-point of 34 kilogs. per sq. mm. The same material showed

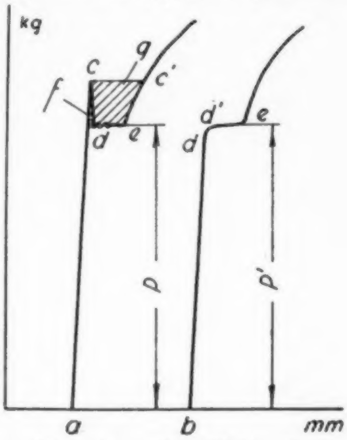


Fig. 11.—Theoretical stress-elongation diagram for mild steel.
(a) Hard-sprung machine.
(b) Soft-sprung machine.

TABLE III.

No.	Diameter of Test-pieces, Mm.	Mean Yield Range in Kilogs./Sq. Mm.	
		1 Soft Springing.	2 Hard Springing (lower yield-point)
1	3·5	33·4 33·1 33·1 31·7	33·6 31·8 34·8 31·6
2 3	4 4·4	33·7 34·7	32·6 34·3
4	6	33·8 33·3 34·9	34·6 33·8 34·4
5	7·5	34·2 34·6 35·2	35·2 37·1 35·7
6	9	35·7 34·3 35·4	36·9 35·8 35·2
	Mean value ..	34·0	34·2

2 Pomp and Krisch. *Mitteilungen*, K.W. Inst. for Iron Research, 19, p. 187 (1937).
3 Siebel and Schwaiger. *Metallwirtschaft*. 23, p. 701 (1937).

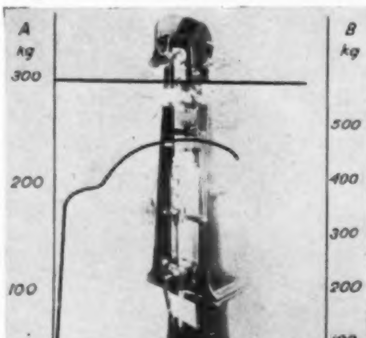


Fig. 8.—300-kilog. Amsler machine.

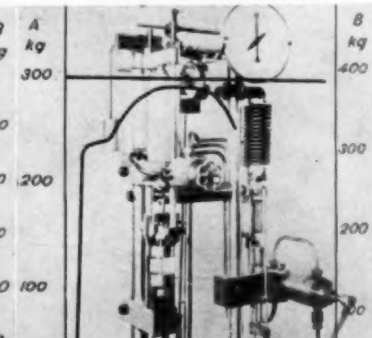


Fig. 9.—4-ton Amsler machine.

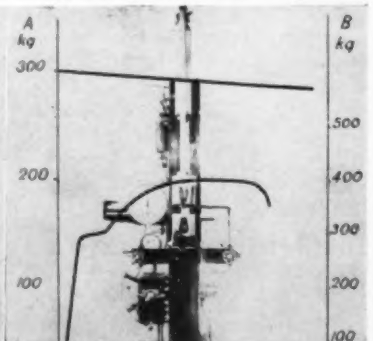


Fig. 10.—3-ton Amsler machine.

grip holder upon indicated force in various types of tensile machines.

in hard-sprung machines recording the usual diagram with load drop on the average a lower yield-point of 34·2 kilogs. per sq. mm. According to these test results, therefore, it may be assumed with fair certainty that in stiff machines the lower yield-point corresponds to the actual yield load of mild steel. According to Fig. 11, therefore, the load P with hard machine springing (Diagram *a*) is approximately equal to the load P^1 with soft springing of the machine (Graph *b*). With soft spring loading, the rectilinearly rising stress-strain curve passes gradually over from *d* to d^1 into the section *d–e*. The upper yield-point *c* with hard springing (*a*, Fig. 11) is absent in such a case, and the work equivalent to the area *f* is thus eliminated. This view is in contra-distinction to that of other research workers,[2, 3] who take an appreciable surplus of work *g* between the points *c*, *d*, *e*, c^1 for granted. In the absence of surplus of work, it is comprehensible that the yield range with soft-sprung machines is traversed steadily, without severe jumps in the load, as may be observed in all tests of this kind. The drop *c–d*, Fig. 11*a*, from an upper to a lower stress, may be explained with hard-sprung machines, as due to the reaction of the elongation of the test-pieces upon the indicator of force. The cause for a super-elevation of the stress in hard-sprung machines, giving the illusion of an upper yield-point at *c*, has not yet been explained exhaustively. This phenomenon, however, should be directly connected with the error in the tensile machine which is caused by the working conditions (inertia effect of the pendulum dynamometer, loading speed, etc.), and not, as heretofore assumed, with a peculiar feature of the material, soft steel.

If Pomp and Krisch[2] have ascertained elongation speeds during their tests in the range of the yield limit which are higher than those indicated in earlier works,[4] this should be attributable, apart from the inadequate resilience of the tensile machine, to the test speeds selected. It should indeed be difficult for the material to yield at elongation velocities amounting to 0·1 to 0·03% per second as ascertained at the time, if the test is so arranged that the lowest elongation speed imposed by the machine upon the test-piece is, from the outset, higher by a multiple (test duration of only approximately 15–30 secs., as against 5 mins. or more). The tests of Siebel and Schwaiger,[3] as well as those of Pomp and Krisch, were effected with inadequate springing for the soft resilience machine, so that compared with hard-sprung machines it was not possible to determine any fundamental difference in point of elongation speed and course of stress at the yield limit.

Conclusions

It is evident from the above results that the springing of tensile machines has a definite influence on the formation of the stress-strain diagram at the yield limit of mild steel. They demonstrate that the moving grip-head on a hard-springing machine gives the characteristic load drop known in connection with mild steel. If a soft springing element is interposed between the force applied and the lower loading grip-head, the load drop will be absent in these diagrams. The increase in length between the specimen holder is recorded under these circumstances by a line passing over in a short bend and rising gradually. This shows clearly that on the one hand uniform increase of the distance between the specimen holders, during the loading test (approximately equivalent to normal elongation of the test-bar in position), will, in the case of hard-sprung tensile machines of the customary pattern, entail a reaction of the measuring grip holder upon the dynamometer, which is expressed by a distinct load drop in the diagram. On the other hand, it is seen that by interposing a resilient component—that is, an elastic tensile machine—no reaction of this kind upon the dynamometer reading is present. In such a case the variation of length between the clamping heads is compensated by the flexible intermediate element, and will remain perfectly devoid of the disturbing influence upon the power reading. With soft-sprung tensile machines, therefore, the indicated force will be unaffected by the modification in length of the test-piece, and the graph traced by the machine will reproduce the actual course of progress of the stress as a function of the strain, and that not only in the yield range, but also while the specimens break.

This view is confirmed by a series of further tests on tensile machines of different sizes customary in laboratory practice. It is found that on three machines of 5–50 tons maximum load capacity, where a considerable reaction of the indicating grip holders upon the indicated force is present, stress-strain diagrams are recorded with distinct upper and lower yield-point, which, in addition, show a severe stress drop at the break of the test specimens. In contrast to this, no kind of load drop obtains in the yield range of mild steel in machines with little reaction of the indicating grip holder upon the indicated load. The upper and lower yield-points have disappeared, and the yield process is reproduced by a gradually and steadily rising diagram section. This shows that the diagrams recorded with load drop do not correspond to the true progress of the stresses, but are attributable to faults in the design of the tensile testing machines, which are primarily to be found in the reaction of the indicating clamping head upon the indicated load. The diagrams of mild steel obtained on customary tensile machines of the present day, with upper and lower yield-point, do not coincide with the facts. Soft steel does not yield in the usual tensile test at the lower yield-point under a stress lower than the upper limit, originally higher, believed to initiate the yielding.

On the basis of a comparative compilation of the stress values at the yield limit of mild steel tested on machines with hard and soft springing, it has furthermore been possible to ascertain that, subject to soft resilience, the material enters directly into the yield range correlative to the so-called lower yield-point. No kind of super-elevation of stress occurs, and a surplus of work, causing accelerated elongation, is not present. The view about the theoretical stress-strain diagram, according to which an appreciable surplus of work, entailing appreciable elongation speeds in the yield range of mild steel, is taken for granted, is not borne out by these results.

If appreciably higher yield velocities at the yield limit were determined by other research workers than those disclosed, this will be due either to inadequate springing of the machine operating with reaction of the indicating specimen holder upon the indicated stress, or to the use of too high a test speed in the yield range. The fact that the upper yield-point is absent not only on mechanically sprung machines, but that the same effect is determined equally with hydraulic-pneumatic springing, whether the test-pieces are large or small should further vouch for the accuracy of our above arguments.

Furthermore, tests carried out during test periods of several minutes, 1 hour and up to 40 hours, show that the loading speed has a marked influence upon the position and the occurrence of the upper yield-point. The results of these tests show that the upper yield-point does not occur with mild steel if the specimen is loaded very slowly. In such cases the diagram track in the yield range is parallel to the abscissa axis, and takes its course without any material disturbing load jumps in zig-zag fashion. Also the yield speed remains exceedingly small, which shows that in soft-sprung machines the material does not start to yield from the upper yield-point, and does not traverse the yield area dynamically. This test permits the accumulation that surplus energy is not present at the yield limit.

Generally, it may be said that the load drop on the yield limit in the tensile test of mild steel is a phenomenon attendant on the design of the tensile machine, and cannot be connected with a peculiar feature of the material contingent on the actual processes within the steel. The theoretical stress-strain diagram and the diagrams obtained on the usual tensile machines with upper and lower yield-point do not conform to reality. A diagram true to actual actions, which reproduces chronically the stresses correlative to the particular elongations, is only possible on soft-sprung machines where the reaction of the variation in the length of the specimens upon the indicated load is absent.

4 G. Welter, *Metallwirtschaft*, 15, pp. 960-964 (1936).

Cartelisation in the World Aluminium Industry* Part V

By Robert J. Anderson, D.Sc.

The disparity between the extensive possibilities of production and the limited possibilities of consumption has long presented an economic problem, and the cartel movement is an effort to control producing and marketing activities. In this, the concluding article of the series, the author reviews what has been accomplished during the last decade and concludes that the cartel movement in the world aluminium industry has been greatly beneficial.

IN conclusion it is advisable to review what has been accomplished during the last decade by the international cartel of aluminium producers. Its operations have effected important results in several directions, and these are to be considered briefly. In addition, some of the advantages claimed for cartel management of the aluminium industry are presented.

First, however, attention should be directed to the fact that new significance has attached to the whole cartel movement since the World War. Theretofore, cartellisation was generally regarded as chiefly economic in character and adaptable mainly for dealing with special economic difficulties arising in industry. But now it is considered widely as a method to be applied for the management of all industry under governmental supervision. That is to say, cartellisation is looked upon as a suitable means by which a managed economy can be substituted for free competition in the capitalistic system. Thus, the cartel movement has gained political importance since the War and especially during the last industrial depression. Besides, public opinion is now less hostile to cartels than formerly. International cartellisation is also seen as facilitating business in the face of high tariff walls, nationalism and difficulties in exchange transfers.

Cartel management by the Alliance Aluminium Cie. and its predecessor has been considered as specially beneficial to the associates in connection with the actual production of the metal. One of the most important advantages claimed has been a reduction of costs. This is ascribed to several factors, including more regular operation of works and the diminution of reserve stocks carried by individual producers to supply unexpected demands. Economies have also been secured by the interchange of technical data, pooling of patents and information on methods of production, joint advertising and marketing, as well as by the elimination of considerable charges for transport. It is said that the appreciable lowering of the selling price during the last decade has been made possible by the savings in production and other costs.

With the closing of inefficient plant and diminishing of stand-by capacity, costs can be still further reduced over the long term. As is known, the sales of individual companies may fluctuate considerably from year to year, but the total sales of all tend to vary much less. (Of course, during periods of general business depression total sales fall off markedly.) Under cartel administration metal can be transferred among the companies and supplied where most needed. If works are to be enlarged less extension should then be required by individual companies to provide for temporarily high demands. Moreover, production programmes can be laid out more assuredly for relatively long periods. By avoiding too great enlargements of plant and by maintaining pooled stocks at a minimum, financial charges are lowered.

During the last industrial depression the Alliance Aluminium Cie. restricted production by its associates in order to control stocks. At the end of 1931 the total supply of aluminium pig held in stock by the members was about 218,000 tons. Stocks at the close of 1932, 1933, 1934, and 1935 were approximately as follows: 153,000 tons, 135,000, 140,000, and 100,000 tons, respectively. Output was reduced to about 35% of capacity at one period during the last depression.

Cartels cannot overcome generally chaotic business conditions but may mitigate the economic consequences thereof. As to this relationship a comparison of the fluctuations in world smelter output of the principal non-ferrous metals during recent years may be found of interest. World output of primary aluminium dropped 49% over the period 1929 to 1933, and then rose 83% to 1935. The corresponding declines and advances in world output of the several other metals were as follows (the low points having been reached in 1932 or 1933): Copper, −51% and +61%; lead, −34 and +19%; tin, −48 and +45%; and zinc, −46 and +70%. The direct comparison is mostly unfavourable to aluminium. This may be explained in part by the small output in the United States during the worst year of the depression and in part by the fact that the demand for aluminium is still rather elastic. In respect of prices, however, the resistance of aluminium to deflationary influences has been better than that of the other metals.

In the mercantile branch of the aluminium business, cartel management has made possible a reduction in the number of sales representatives and middlemen. Selling costs have consequently been decreased. It is stated that unnecessary sales between producing countries have been eliminated, thus avoiding the payment of freight charges and import duties. By maintaining fixed prices for all countries under cartel influence dumping, with its attendant evils and anomalies, has been practically abolished. Furthermore, the cartel has financed some export sales for which long time credits were required.

The price policy of the Alliance Aluminium Cie. and its predecessor is regarded by the producers as having been advantageous for consumers. So long as stable prices are in prospect the consumers can hold stocks at a minimum and avoid speculation. As shown previously, aluminium prices during the decade 1926–1935 were relatively stable. With the exception of revisions connected with currency devaluations, only reductions were made in the fixed prices during that period. In modern cartel administration it is recognised that selling prices must be moderate and be kept reasonably steady. The fixing of moderate prices is dictated by self-interest in order to ward off potential competition from two sources. One is the competition from outside interests, and the other is that from substitute materials. If high prices are fixed, new companies or large consumers may be attracted by the indicated profits and start production, and consumers generally will seek to use materials which can be substituted at less cost. The policy of setting prices as low as feasible is also recognised as necessary to increase demand and promote new applications.

The position has sometimes been taken that international cartellisation is conducive to the annulment of import duties since the agreements provide for reservation of the

* *Continued from May Issue.*

national markets to home producers. But this is not the case in practice because duties are usually of foremost importance in the negotiation of agreements and in fixing quotas. In the aluminium industry the producing countries generally have levied high import duties, and existing tariffs have been raised by countries where aluminium production has recently been initiated. So far, import duties on aluminium have not been affected by cartellisation of the industry. At the same time the indications are that international agreements maintained for long periods lead to the reduction of duties and their stabilisation at moderate rates[6].

Finally, cartellisation is regarded as advantageous to labour since it tends to promote regularity of production and hence more assurance of steady employment. Also, the maintenance of prices at remunerative levels is seen as enabling employers to minimise reductions in wages during periods of depression.

Just now the question arises as to whether the present international aluminium cartel can be maintained over the long term. Since 1931 aluminium production has been undertaken for the first time in five countries, and several others will probably begin to make the metal within a few years. In addition, the capacity of most producers, both old and new, is being expanded. The export market has continued to contract and should be smaller in the future with further decrease in the number of non-producing countries. This situation is, of course, a reflection of nationalistic endeavours toward self-sufficiency. It obtains not only in respect of aluminium but also of other commodities in general. The rise of many more new producers in the world aluminium industry might disrupt the international cartel organisation unless consumption can be markedly increased. At any rate the indications are that producers in nearly all countries will be making aluminium more and more for their home markets (or for associated economic areas, as in the case of the British Empire). This tendency has become increasingly pronounced as the years have passed since the formation of the third international cartel. The advent of outside competition is always a threat to the continued functioning of a cartel. New interests may be admitted to membership or absorbed by associated members of the organisation, and the danger thereby averted.

None of the international cartel organisations in the aluminium industry has prevented enlargements of capacity by members or the entrance of new producing companies. Nevertheless, the existence of the several cartels has been a restraining influence against competitive building, both by associates and outside interests. The character of the industry has been conducive to international agreements, which are considered necessary for the regulation of output, orderly marketing, economical production, and the periodic adjustment of supply to demand. Latterly, the downward trend of aluminium prices has been increasingly favourable to consumers and has helped to expand the field of applications.

From the viewpoint of planned economy the conclusion is reached that the cartel movement in the world aluminium industry, especially in its more recent development, has been generally beneficial.

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Service Life of Tin-base Bearing Metals

WHITE bearing-metals rich in tin have already a century of successful use behind them, and researches are now proceeding to ensure that they maintain their reputation under the often more severe conditions of service that obtain to-day. In certain types of internal-combustion engine, where the loading is very severe, white bearing-metals have sometimes cracked and broken up. The study of these failures has led to modifications in design and operating conditions, and further progress should follow fresh knowledge.

A recent paper by D. J. Macnaughtan discusses typical failures, and the factors underlying them. Tests revealed the degree of stress in white-metal linings on thin steel shells due to thermal expansion and contraction, and showed to what extent the stress could be relieved by creep. Other probable causes of tensile stresses are discussed, and the author considers at what temperature the fatigue properties should be compared in view of results obtained at room temperature, and 150° C., with bearing metals containing additions of cadmium and lead. These experiments suggest that less than 2% of cadmium and no lead should be permitted in white bearing-metals.

Hot-tinning Methods

The fabrication of pans, dishes, churns, wire, tubes and other products from copper, steel and other metals produce a surface which requires degreasing, pickling and fluxing before it will take a satisfactory coating of tin by hot-dipping. In this publication practical details of methods employed are discussed by E. J. Daniels, M.Sc. A survey of the patent, scientific and technical literature on the subject is given, and in addition to a discussion on degreasing, pickling and fluxing articles prior to the actual tinning, formulæ are given for the baths suitable for the varying types of articles. The difficulties sometimes met in tinning brass, bronze and aluminium necessitate special treatments for these metals.

Copies of these publications may be obtained free of charge from the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C. 2.

Developments at Jarrow

Two important new industries have commenced operations which mark a new stage in Jarrow's development after a long period of depression. In this article brief reference is made to some of the new plant and equipment.

AFTER strenuous and, frequently, discouraging work by Sir John Jarvis, two new works were officially opened recently at Jarrow. Over four years ago, when Jarrow was suffering badly from industrial depression, Sir John initiated an effort to bring some relief to the town and the new industries which have recently commenced production, form a part of the scheme to revive industry in the town. The two works comprise the Jarrow Tube Works, which is sponsored by Messrs. Stewarts and Lloyds Ltd. and Tubes Ltd., and Jarrow Metal Industries.

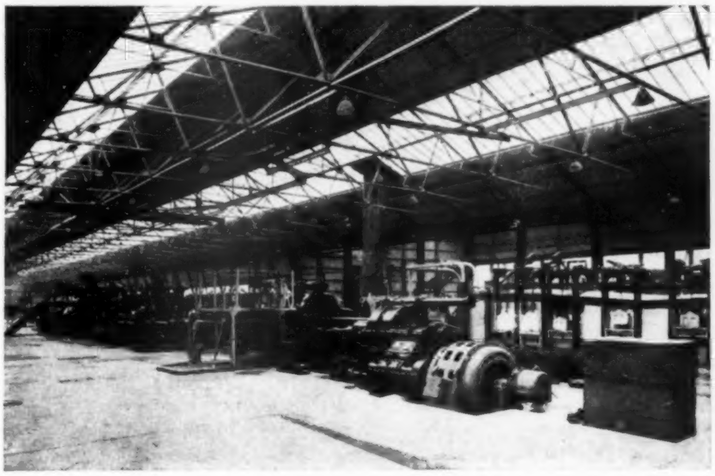

Fig. 1.—General view of the mill of the Jarrow Tube Co., Ltd., showing the piercer mill in the foreground.

The tube works, which are erected on the old site of Palmers Shipbuilding Co. and adjacent to the works of the late Tyneside Brass and Copper Tube Works, are designed and equipped for the manufacture of hot finish, cold-drawn seamless to fine limits, and bright annealed tubes in sizes ranging from 3 in. down to the smaller diameters, for which there is an increasing demand. For this purpose a piercing and rolling unit by Maschinenfabrik Meer A.-G. has been installed, together with a Pilger mill, reheating and annealing furnaces of the most modern type.

The mill buildings cover an area of 110,000 sq. ft. and are very spacious, well-lighted and well ventilated. Electricity is used on a comprehensive scale throughout the mill. The main electrical plant and equipment, which have been installed by the General Electric Co. Ltd., include rolling mill motors, main and auxiliary switchgear, transformers, about 100 auxiliary motors, motor control gear, a continuous bright annealing furnace, lighting fittings and lamps, distribution gear, and high tension and low tension cables. Power is supplied from the 20,000-volt mains of the North Eastern Electric Supply Co. Ltd. and transformed to 5,500 volts. It is then taken to an S.V.D. type switchboard consisting of six panels. While one of the rolling mill motors and the motor of a Ward Leonard set for the Pilger mill are supplied at 5,500 volts, distribution is general at 440 volts, which is controlled from a nine-panel pedestal type industrial switchboard.

The billets from a reheating furnace are passed first through the piercer mill, shown in the foreground of Fig. 1; the tubes then proceed to the Pilger mill. On leaving the latter mill they are cut to length and subsequently delivered to No. 1 cooling bank, Fig. 2, and later reheated and taken through a reducing mill. The process of straightening is next undertaken in a specially designed machine. Subsequently, the tubes pass to cooling bank No. 2, and if required for cold-drawing to fine limits, to a swaging machine. The tubes are drawn on a series of draw-benches; for a special finish they are taken to a continuous bright annealing furnace.

The continuous bright annealing furnace is of the most modern design for dealing with mild steel tubes. It provides an anneal possessing finish, quality, uniformity and precision of an outstanding character. The furnace is 171 ft. long overall, and is designed to handle tubes up to $3\frac{1}{2}$ in. outside diameter, and 20 ft. in length; the normal output is 16 to 17 cwt. per hour, and the electrical loading is 220 kw. The normal operating temperature is approximately 800° C. and this is automatically controlled.

The most interesting of the installations at the new works of Jarrow Metal Industries Ltd. is a 15-ton capacity electric arc furnace which embodies many recent improvements. The casing, electrodes, linings, etc., are of standard design and construction, but the main point of interest is the type of control. It is a Tagliaferri furnace and it has been installed by Metatectric Furnaces Ltd., who have a licence to control and build these furnaces in Great Britain and the British Colonies. Fig. 3 shows the furnace in operation.

The interesting feature about this furnace is the Tagliaferri regulator which is designed to reduce the number of moving parts to a minimum and so to enable the maintenance engineer to make normal working adjustments

Fig. 2.—No. 1 cooling bank, with a hot saw in the foreground.

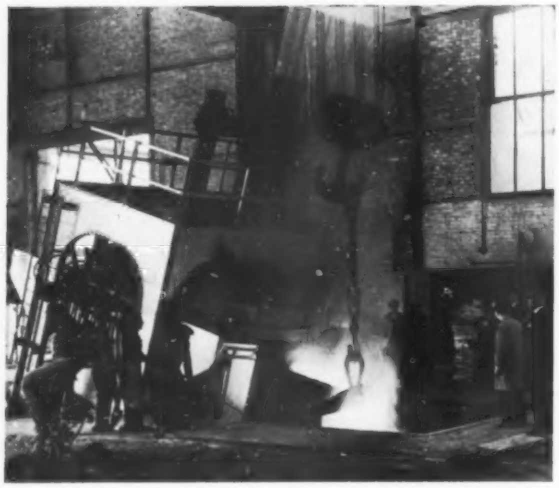

Fig. 3.—The 15-ton Tagliaferri furnace in operation at the works of Jarrow Metal Industries, Ltd.

without difficulty. By using hydraulic rams for electrode-raising and lowering, for tilting the furnace, operating the door, etc., the actual mechanism about the furnace is reduced, and since all the main parts are hydraulically operated there is no danger of any jamming or sticking. The whole of the mechanism controlling the three electrodes is contained in a box, 30 in. by 10 in. by 8 in. and it is so designed that the movement of the electrodes is automatic with the working requirements of the furnace.

These works, which we understand have many orders on hand and in prospect, will make a great difference to Jarrow and will greatly assist in reviving an area which for many years made valuable contributions to the former industrial prosperity of Tyneside.

Activity in the Canadian Steel Industry

The Sydney (Nova Scotia) steel plant of the Dominion Steel and Coal Corporation has been working at full capacity during the current year to date. Early in 1938 the Corporation received a 20,000-ton rail order from the Canadian National Railways to cover seasonal requirements. There has been some easing-up in the domestic demand for iron and steel products, but not sufficient to make any difference in the rate of operations.

The large English order for billets, wire rod, etc., continues to take about 35% of the plant output. This contract, entered into towards the end of 1936, provides for the shipment of several hundred thousand tons of steel products to England over a period of four years. Some consideration has been given to the reopening of the tin-plate mill at the Windsor (Ontario) plant purchased sometime back from the Canadian Steel Corporation, Ltd., but in view of market conditions this plan is in abeyance.

Last year the Corporation shipped from the Wabana mines, in Newfoundland, between 1,600,000 and 1,700,000 tons of ore, the largest quantity reported for many years. This was distributed in the following proportions: Sydney plant, 650,000 tons; Germany, 800,000 tons; England, 200,000 tons; and the balance to the United States. Shipments to Germany this year are expected to equal those of 1937, and the Sydney plant will probably take the same quantity. Shipments to England will possibly be slightly less, and present indications are that iron-ore shipments in 1938 will be in excess of 1,500,000 tons, and may equal the 1937 figure.

War Office Appointment

DR. H. J. GOUGH, late Superintendent of the Engineering Department of the National Physical Laboratory, has commenced his new duties as Director of Scientific Research at the War Office.

Beryllium

METALLIC beryllium and high-beryllium aluminium have a Young's modulus greater than that of steel; beryllium copper resembles steel in many ways. In ternary alloys it can be heat-treated and hardened to develop tensile strengths in excess of 200,000 lb. per square inch with Brinell hardnesses of 385 or more. It has an electrical conductivity more than twice as great as steel, low mechanical hysteresis, and a salt-spray corrosion endurance limit higher even than stainless steel. The endurance limit in air is between 35,000 and 44,000 lb. per square inch. Beryllium copper presents a unique advantage to fabricators because its soft, workable condition after high-temperature quenching adapts it for forming into intricate shapes which may subsequently be uniformly hardened by a gentle reheating temperature.

C. B. Sawyer and B. R. Kjellgren[1] deal at length with the question of extraction of the oxide and state that metallic beryllium may be produced in alloy form by direct reduction of its oxide by means of carbon or hydrogen, or it can be produced unalloyed by electrolysis of its anhydrous fluoride or chloride salts above or below its melting point, and by a chemical reduction of the same fluoride or chloride with sodium or magnesium. Although the reduction of the fluoride or chloride either electrolytically or by sodium or magnesium yields a product generally useful in alloys, this process has, however, disadvantages.

Beryllium metal has about the same density as magnesium, but greatly exceeds both magnesium and aluminium in its melting temperature which is 1,285° C, making beryllium, for practical purposes, the only stable light metal with a high melting point.

This melting point is close to that of iron, and its linear coefficient of expansion and calculated Young's modulus of elasticity are also close to those of iron. The metallurgical handling of pure beryllium metal still remains an unsolved problem, Kroll[2] classes beryllium with silicon in alloy habit and with chromium and bismuth in behaviour under rolls. An interesting factor is that magnesium, cadmium and zinc occur with beryllium in the same group in the periodic table and have the same crystallographic habit, being hexagonal, close-packed.

Beryllium is to copper almost what carbon is to iron, and the largest present commerical application for beryllium is in the form of various alloys with copper. In steel, however, heat hardening is possible to some extent with diminishing carbon content down to 0·1% but binary beryllium copper will not heat harden when the beryllium content is less than about 1%, yet third-metal additions, such as iron, cobalt, nickel and chromium, have the effect of permitting heat hardening with lower beryllium contents, sometimes as low as 0·1%.

Heat hardened beryllium copper, especially in the form of ternary alloys, has been exposed to temperatures of about 300° C. or more and can be exposed continuously to temperatures of 150 to 200° C., which range is sufficient to cause loss of temper in other work-tempered springs.

Centreless Grinding

FOR the precision grinding of stainless and other steel bars, Edgar Allen and Co. Ltd., have recently organised a special section including a Churchill centreless grinder, a reeling machine, etc. The work undertaken ranges from ⅛ in. to 1¼in. bars up to 15 ft. long, and according to the amount to be removed, the grinding is completed in three passes which remove about ten-thousandths at a time except at the final pass where the cut is lighter. The speed of pass is about 15 ft. per minute. All bars are tested for roundness, parallelism and size, the last being guaranteed between plus and minus ·0005 in. and a limit of ·00025 in. can be worked to, if necessary. Higher speeds and accuracies can be obtained.

1 *Ind. Eng. Chem.* 30.5. 501-505.
2. *Met. and Alloys.* 8, 349.

Correspondence

High-Speed Strip Rolling

The Editor, METALLURGIA.

Sir,—In an article published in the April issue of METALLURGIA dealing with rolling speeds, Mr. Davies mentions that Continental manufacturers of rolling mills have hesitated in following the lead given by American rolling mill manufacturers in respect of increased speeds. As one of the oldest and most specialised manufacturers of rolling mills we would like to point out the following :—

The problem of increased rolling speed is very different for European rolling mills than it is for American mills. In the United States, individual orders for specific widths and gauges are very much larger than are obtainable in Europe, where manufacturers have to cater for smaller individual orders and for a larger clientele. This question of speed is primarily one for the decision of the user of the machine, not for the constructor, as the user has to consider such factors as quantity and finish, particularly the quality of the rolled material, and every manufacturer knows that the demands of customers become increasingly exacting.

We have built and supplied high-speed rolling mills for many years, either for breaking material down for final rolling (our customers generally preferring lower speeds for final rolling), or for equalising material by a minor reduction. The question of speed has been as closely studied in this country as in the United States or elsewhere, but it has been found that the method mentioned is better, in the long run, for European requirements.

If, however, it is considered that mills with higher speeds are suited to particular applications, we should be only too pleased to give quotations and details of our high-speed mills such as are in use by many prominent works.

Köln—Ehrenfeld, Germany. Inh. : R. MÜLLER.
May 11, 1938.

The Editor,

Sir,—I have been interested to read the letter from Mr. Müller which refers to my recent paper on the subject of high-speed strip rolling. This really confirms my statement that generally German practice continues to favour low speeds, and explains that this is due to the fact that in Europe small individual orders varying in width and gauge are the rule, whereas in America, orders for large quantities in standard dimensions are obtainable. This difference is fully appreciated, but in England where small and varied orders are also most usual, it has been proved advantageous and economical to install mills running at high speeds.

I entirely agree with your correspondent that rolling speed is mainly a question for the user of the mill, but it is for the mill constructor to offer mills which can be worked efficiently at whatever speed his customer requires, and it is surely desirable in the interest of the industry, for the engineer to be in advance of requirements in this respect. Owing to the progressive policy of my firm, users have gradually found that a small number of mills operating at two or three times the classic speed of 25/30 metres, will give a greater production at a lower cost per ton than a much greater number of slow speed mills, and as stated in my paper, few strip-mills, whether for steel or non-ferrous metals, are now installed for a speed of less than 45 metres per hour, rising to 70 or 80 metres for mills producing light gauge strip, where the coils are consequently long, even when the weight of coil is small.

As indicated by Mr. Müller, the most convenient speed for any strip mill must depend on the class of rolling in view, but it is somewhat surprising that his customers, whilst apparently adopting higher speeds for preliminary rolling, prefer slow speeds for finishing. In most cases here, rolling speeds progressively increase from breaking down to finishing, the latter process now being successfully accomplished at the highest speeds. As mentioned in my paper, the most delicate rolling operation, that of finishing aluminium foil, is being carried out at the maximum possible speed of 200 metres and more. Again, in the case of steel where heavier coils are available, four-high mills take the initial heavier reductions at speeds of the order of 45 metres and finish at 90 to 120 metres.

If space permitted, I believe your correspondent could be convinced that it is quite a mistake to conclude that low speeds (by which I assume speeds below 45 metres are meant) are actually better for European requirements. I would point out that I am quite aware (as stated in my paper) that German firms such as Mr. Müller's are building high-speed mills, but it seems clear that the European strip-rollers have not generally favoured even moderately high speeds, and as a consequence, the developments of the high-speed rolling mill in Germany have not advanced as it has during recent years in this country.

Bedford. Yours truly,
May 24, 1938. C. E. DAVIES.

Alloy Nomenclature

The Editor,

Sir,—Is it not time that agreements were reached between the metallurgists and the metallurgists as to the correct way of describing alloys ?

It was, I believe, decided many years ago by a Committee of the Institute of Metals that the chief constituent in an alloy should come last. Under this system duralumin would presumably be called a manganese-magnesium-copper-aluminium alloy.

The authors of papers before the Institute apparently adhere to this ruling, but outside the Institute, the more general method appears to be to put the chief constituent first, which seems far more logical.

We talk about an aluminium alloy in general terms and an aluminium-copper alloy as an aluminium alloy containing copper as a hardener. It seems clear that authors who still put the chief constituent last are by no means sure of their ground and the height of absurdity appears to have been reached when an author talks of the "magnesium-rich aluminium-magnesium alloys."

Is it not time that the matter were again discussed and decided by an authoritative body on which practical men who are making and selling metals and alloys, are properly represented ?

London, Yours faithfully,
May 20, 1938. FREEMAN HORN.

The Editor,

Sir,—I have read the letter from Mr. Horn on Alloy Nomenclature with interest but think it will be difficult to obtain agreement to any system. In some of the alloys used to-day, there are at least six elements, and no matter in what order these are given, the result is too cumbersome for ordinary use. As an example, one might take the alloy RR 56 ; this is covered by D.T.D. Specification 130, which gives limits for no fewer than six elements.

It is obvious to me that one must have some short title which may not fully describe the constituents. Further, it must be taken into consideration that some alloys have firmly established names which may not fall in line with any proposed scheme. We speak of cupro-nickel when the copper is the major constituent, and yet we have phosphor-copper where phosphorus is the minor constituent.

For works' usage, I have started the practice of referring to alloys by their specification numbers wherever applicable. For example, stainless steels are referred to as S 61, or S 80 as the case may be. Where alloys are not standardised, I think the only thing one could do is to refer to them as, say, complex Cluminium alloys of a certain analysis.

Glasgow, Yours faithfully,
May 23, 1938. J. ARNOTT

The Editor.

Sir,—I have read Mr. Freeman Horn's letter on the above subject with interest.

It is very desirable that there should be some standard usage, and it seems to me that the Institute of Metals is the most likely body to produce such a standard.

Whatever is promulgated by such a body, it must be realised, however, that some time must elapse before it soaks down into general use, as industrialists usually pick their names on a basis of euphony and ease of pronunciation, rather than upon a foundation of scientific nomenclature.

Nechells, Yours faithfully,
Birmingham, 7. L. AITCHISON.
May 31, 1938.

Arctic Boulder

The Editor,

Sir,—I have read with the greatest interest the short article in your May issue dealing with the subject of the Arctic boulder of solid iron, and would like to find out if this natural carbon steel of the Blue Mountain on Disko Island contains nickel. If this natural carbon steel contains no nickel then it is obviously of terrestrial origin, and it will be an easy matter to prove that the meteor being drilled is a meteorite.

If, however, there is nickel in this natural carbon steel of the Blue Mountain, then two highly important points arise; either the whole Blue Mountain itself is meteoric, or a terrestrial source of iron which contains nickel has been discovered for the first time in history. Hitherto, it has been assumed, probably correctly, that all celestial iron contains nickel, and that this element is never found in terrestrial iron.

Ealing, London, W. 5. Yours faithfully,
May 20, 1938. D. BROWNLIE.

(With the object of securing further information we communicated with Professor Dr. C. Benedicks, whose reply is appended.—ED.)

Sir,—It is well-known that the Disko iron, brought home by Nordenskiöld, contains about 0·5–2·5% Ni. Nordenskiold considered this as a proof of its meteoric origin, while the geologists maintained that the iron must have been formed on the earth, in situ. This opinion has been corroborated by some microscopic studies made by me in 1910.

Similar occurence of terrestrial iron, though in quite a small scale, have been found at several places, as at Bühl in Germany.

The note that the block now drilled contains "pure iron and nickel" is apt to produce some misunderstanding The striking result was that it was metallic throughout; a considerable carbon content (say 1 to 2%) however, exists.

The difficulty of the drilling, at least in my opinion, is not due to some exceptional hardness, but to the fact that the material is brittle; fragments are formed during drilling which will rotate in the hole, causing heavy stress on the diamonds. The drilling, however, was quite successful.

Stockholm VA. Yours faithfully,
June 4, 1938. CARL BENEDICKS

An illustrated booklet dealing with those sections of the Factories Act, 1937, which refer to heating, ventilation, lighting, clothes drying and hot water facilities in the premises that come within the scope of the Act has been published by the British Commercial Gas Association and is obtainable free of charge from Gas Industry House, 1, Grosvenor Place, London, S.W. 1, or from any of the gas undertakings.

The purpose of this booklet is to show employers how gas apparatus can be used to enable their premises to comply with the Act in an economical and efficient manner. It shows how gas can be used in a very large variety of premises, large and small; from automatic gas-fired boilers for steam heat for air-conditioning or for central heating to overhead radiant panel heaters for small workshops.

Aluminium Display in Canadian Pavilion at Empire Exhibition

AN interesting and informative display in the Canadian Pavilion of the Empire Exhibition is that by Aluminium Union, Ltd. The back walls of the stand attractively display, by means of a multi-coloured large-scale drawing, the process of the production of aluminium from mine to market. This mural design has been so skilfully and simply executed that the process is readily understood by the non-technical. First is shown the mining of bauxite in British Guiana and the refining process to the stage when the alumina is charged into a bath of molten cryolite, then how carbon anodes are made. The supply of electric current—an important factor in the production of aluminium—is emphasised by a photograph of one of the large hydro-electric power stations employed.

Display of Aluminium Union, Ltd., in the Canadian Pavilion of the Empire Exhibition at Glasgow.

Various semi-fabricated products from ingot are displayed, including strip and sheet, castings, forgings, extrusions, mouldings, tubing, wire, foil, paint pigment; while various working models demonstrate the many advantages of aluminium and its alloys. A booklet, entitled "Aluminium," has been specially designed and produced for distribution from this stand. It deals in graphic form with the basic preparation of aluminium from bauxite, applications of the metal, and how aluminium is marketed. The booklet is well illustrated, and has a centre section consisting of a single column photographic inset. The text is in four languages throughout—English, French, Spanish and German,—and the booklet is printed in two colours, with the addition of aluminium as a third colour on the covers. A useful feature is that the Company's overseas offices are detailed on the back cover, below a map showing significant towns.

Chromium-Molybdenum Steels for Mining Equipment

MINING equipment is subjected to an unusually severe combination of shock, high stresses and abrasive wear. For castings where considerable resistance to abrasion is required, but in which the equipment is not subjected to severe shock, a number of alloy steels are widely used. Analysis of three of these, according to Herzog* area s follows:—

Carbon	Up to 0·60	Up to 0·45	Up to 0·79
Chromium	0·80–1·00	2·75–3·25	1·40–1·60
Molybdenum ..	0·30–0·40	0·40–0·60	0·30–0·40
Nickel	—	—	0·70–0·80

Though optimum physical properties of any of these three steels are developed by oil quenching and drawing, rather satisfactory combinations of properties may be obtained by ordinary annealing for some applications or by air-quenching and drawing for others. The simplest of heat-treatments are frequently very essential for castings used in the mining industry due to their shape and size.

* "Mining Needs" by G. K. Herzog, Vol. 102, No. 18, p. 39.

Institute of British Foundrymen

Thirty-Fifth Annual General Meeting and Conference

A summary is given of the proceedings at this conference and particular attention is directed to the various subjects discussed at the technical sessions.

FOR the first time, the annual conference of the Institute of British Foundrymen was held at Bradford, on June 14–17. An enthusiastic attendance of took full advantage of the excellent programme arranged members by the West Riding of Yorkshire Branch, which contributed so much to the general enjoyment. In view of the success achieved, the various committees are to be gratulated on the efficient way in which the arrangements were carried out.

The annual report of the Council was presented at the business meeting, and it is interesting to record that the year ending April 30, 1938, proved one of the most successful in the history of the Institute. The record membership announced a year ago has been substantially increased, and is now 2,220 ; the finances are in a sound condition, and every department of the Institute's work has made progress. This happy position is due largely to a recognition of the increasing value of the Institute to the industry, and to a growing recognition by the individual foundryman of the value of membership.

At this opening meeting the various awards and diplomas of the Institute were announced, and it is interesting to note that the second award of the E. J. Fox Gold Medal was made to Mr. J. E. Hurst. Mr. Hurst, who is at present technical director of Bradley and Foster, Ltd., Bradley's Concrete, Ltd., of Darlaston, and of Sheepbridge Stokes Centrifugal Castings Co., Ltd., has, during a period of 25 years carried out a considerable amount of research work on cast iron. His research work has led him to make some important discoveries in connection with the heat-treatment of cast iron and in the development of cast iron suitable for nitrogen hardening. The election of officers and members of the Council was also announced at this meeting. Later a civic reception was accorded the members by the Lord Mayor and Lady Mayoress of Bradford, Alderman and Mrs. Henry Hudson, at the Cartwright Memorial Hall, Municipal Art Gallery, Bradford.

The conference opened on the morning of June 15, at the Bradford Technical College, with an address of welcome by the Lord Mayor of Bradford, who presented the Olivier Stubbs Medal and the E. J. Fox Medal to the recipients. Mr. C. W. Bigg, the retiring president, then performed the induction ceremony and vacated the chair for the President, Mr. J. Hepworth, J.P., M.P., who subsequently delivered his presidential address.

TECHNICAL SESSIONS

In order to cope with the technical papers presented at this meeting, and to provide facilities for discussion, two sessions were arranged to proceed simultaneously ; even so, however, it is difficult to make suitable arrangements for proper discussion of the interesting and informative papers presented. In the following notes an effort has been made to summarise these papers and to present the salient features discussed.

The Randupson Process of Cement Moulding

The use of silica sands bonded with cement and water, in place of the more usual moulding sands, has been developed over a period of seven years. This is the Randupson process, invented by a French engineer, M. Durand, of the Cie Randupson of Marseilles, and developed by the Societe d'Electro Chimie d'Electro-Metallurgie et des Aceries Electriques d'Ugine in the south of France.

The sand-cement-water mixture is rammed round patterns mounted in wooden box parts or in coreboxes or struckled in the manner usual with loam sands. The sand is reinforced at various points with straight irons and staples are embedded where necessary for lifting. This process and its application are described in the paper by Mr. F. W. Rowe.

For the success of this system, a certain well-defined ratio between the amount of water and the quantity of cement must be preserved, the proportion of the water added to the cement-sand mixture must be such that the cement is subhydrated only. The most suitable sand is a fairly pure silica sand of rather coarse grain size—one, for example, in which 70% of the grains remain on a 60's sieve, and reasonable freedom from clay and fine silt is an advantage. The proportions of cement most suitable for various conditions vary from 3 to 15%, with a total water content in the mixture from 2 to 9%. The mixing time is usually between $1\frac{1}{2}$ and $2\frac{1}{2}$ mins., and is usually done in a mill where no milling occurs ; most of the more modern types of mills are suitable for the Randupson sands. The sand must be used within three to five hours of mixing ; any sand remaining unused has to be returned to the mixing plant for reconditioning.

Most existing patterns or methods for moulding can be adapted with very little ingenuity or expense. Little compression is needed, ramming is easy, and the sand can be jolted or vibrated successfully. Even the largest moulds and cores are sufficiently strong, in most cases, to lift after 24 hours' setting and hardening. Casting follows normal practice, but the extraordinary strength of the Randupson mould allows even 20-ton rolls, 15 ft. long, to be cast in an open pit without enclosure of any kind.

Setting time is a disadvantage for small moulds, and in the author's opinion, lessens the appeal of the process where the great majority of the work is cast in green sand ; whilst in larger moulds the extraordinarily speedy moulding possible means that the extra time needed before casting is more than offset by the saving in moulding time—apart from cost considerations.

The author shows the marked savings in time that are possible, especially if a number off a large mould is required from a large pattern. It is evident that what disadvantages there are in the process are comparatively easy to meet, and in most cases are more than compensated by the advantages, such as unusual speed, no need for drying stoves or fuel, no box parts or storage for box parts, castings much truer to pattern, no scabbing, and with suitable sands and working of the process, no blowholes due to much higher permeability. At the present time large tonnages of carbon and alloy steels, cast iron, gun metal, phosphor bronze, and manganese bronze, aluminium alloys and magnesium alloys, are being cast by this process in weights from a few pounds to 40 tons.

Relief of Internal Stress in Castings

Some of the harmful results of internal stresses in castings have been known for a long time, but little attempt has been made to find out what annealing conditions are necessary for the removal of internal stresses ; this paper by Messrs. L. E. Benson and H. Allison is therefore of great interest, as apart from cracks which may or may not be detected before the castings are finished and go into

service, internal stresses may lead to distortion during machining or in service under easy service conditions.

In the authors' experience, distortion of castings and forgings during machining is, in the main, not due to "machining stresses," as is frequently stated, but is due to internal stresses initially, and these are only revealed when the removal of metal on machining disturbs the balance of the internal stresses. Proper annealing can prevent such distortion on machining, except in the case of work entailing very close limits. In steel castings and forgings, at any rate, objectionable internal stresses revealed by machining are not due to casting or forging conditions, the relief of stresses on annealing being essentially a creep phenomenon and for which existing data is not readily applicable.

To ascertain the degree of stress relief to be obtained from different annealing treatments, experiments were made on cast iron, carbon steel, Admiralty gunmetal, and a high-tensile bronze. It was shown that substantial stress relief could be obtained by annealing at approximately the following minimum temperatures :—

Admiralty gunmetal	400° C.
High tensile bronze	500° C.
Cast iron	550° C.
Carbon steel	600° C.

Annealing grey cast iron appreciably in excess of 550° C. will produce measurable growth, whilst annealing certain steel castings, such as molybdenum steel, much in escess of 650° C., but below the critical range, will bring about spheroidisation of the carbide constituent, possibly with very detrimental results as regards the creep strength of the material, which is the property for which these steels are particularly valuable.

For ordinary commercial foundry practice the effect of the length of the annealing period is of secondary importance, but the temperature : stress relief curves are steep, and for this reason sufficient soaking should be allowed for the castings to attain the annealing temperature throughout. One interesting result of the experiments was to show that it is erroneous to assume that in iron or steel castings any large measure of stress relief is obtainable by ageing at atmospheric temperatures or by annealing at temperatures such as 150° or 350° C.

Cooling after annealing from the stress-relieving temperatures, may set up a system of internal stresses as well as cooling after casting or after a high temperature annealing treatment. To avoid this, furnace cooling is recommended, the authors recommending that cooling in a closed furnace to 100° C. is satisfactory, even for such important parts as steel castings for turbine cylinders and large steam chests.

Steel castings are generally annealed at a temperature in the region of 900° C., and are often given a second treatment at 600°–650° C., after rough machining. As internal stresses become dissipated at about 600° C. the internal stresses are not the result of cooling down after casting or forging, but have been developed by uneven cooling after annealing. The authors contend that one properly controlled annealing is preferable to repeated annealings if due regard is not paid to the final cooling conditions. In cast iron the need for annealing will depend upon the degree of internal stress that can be tolerated and the uniformity of temperature that can be maintained as the castings cool down, particularly through the range 550° to 350° C.

English and American Steel-Foundry Practice

The steel-foundry industry in Great Britain is essentially of a jobbing nature, from foundries of all sizes with outputs varying from a few tons per week to several hundred tons per week. This is the view of Dr. C. J. Dadswell, who stated that there have been few British steel foundries laid out for specialised production of a limited variety of castings, with the exception of such cases as mine-tub wheels, railway wagon components and wheels, certain manganese steel specialities, some gearwheels and valve castings, and that only recently have more elaborate methods of production been introduced. In no case does the output of these specialities compare with the output of the largest American foundries producing the same or similar castings.

It is pointed out that there is a marked difference in America and England regarding the categories of size and weight into which castings are divided for making in green sand, skin-dried or dry sand ; and also considerable difference in the kind of moulding mixtures employed for these different sands, this difference in material being most pronounced in the case of American dry sand, which is generally of the synthetic type for all sizes of casting.

Some form of sand control is to be found in most American steel foundries, and particular attention is paid to permeability by those firms working in green sand, a figure as high as 200 being obtained for backing sand. The silica sand used in American dry-sand mixing is somewhat coarser than that used in the green sand, and is coarser than the silica sand commonly used in this country. In England synthetic dry sands mixed on slightly different lines have been used for lighter castings, which would more often be made in green sand in America.

One of the most striking differences in technique practised in America is the casting of locomotive frames with cylinders, boiler saddles and horn block guides cast integrally. The complete moulds are built up in dry-sand cores placed on specially machined steel jigs in moulding pits—using normally 600 cores—and, as instanced in one works, making six-wheel bogie truck castings, are rammed in green sand on a jolt-ram machine of 70 tons capacity.

The most common melting unit for the small American steel foundry is the electric furnace, usually with an acid lining, as compared with the more usual basic lining in this country. For larger outputs both acid and basic open-hearth furnaces are used, the average capacity of such furnaces devoted entirely to the manufacture of heavy steel castings appears to be about 50-ton maximum, whilst in this country, in steelworks making both steel castings and ingots, the larger furnaces are generally of 60-ton capacity.

Continuous casting systems with mechanical mould conveyers are not commonly used in the American production steel foundries. Most of the heat-treatment furnaces in the steel foundries in U.S.A. are fired by oil or natural gas, as against coal, producer-gas, or town's gas in this country, and small castings are normalised with or without subsequent tempering. Heavier castings are annealed and cooled in the furnace, but at higher rates of cooling and heating than used in Sheffield. Fettling-shop methods are very similar in both countries, but the centrifugal airless shot projector has been applied in America to several types of special machines for specialised work, such as for cleaning bogie castings weighing about 5 cwt., each at the rate of one every 2 mins.

Heat-Treatable Aluminium Silicon Alloys

A French exchange paper, presented by M. Gaston G. Gauthier on behalf of the Association Technique de Fonderie (France), gave some of the results obtained in the course of researches made by the laboratory of the Compagnie Alais, Froges and Camarque on heat-treatable aluminium-silicon casting alloys containing, in addition, magnesium, manganese or cobalt. Details are given showing the variation in mechanical properties under the influence of the heat-treatments and under the influence of variations in the contents of Si, Fe, Mg, Mn, Co, and Na.

The investigations were made on sand-cast and chill-cast specimens, but only the results on sand-cast specimens are quoted. The specimens were cast in green sand containing about 5 to 6% moisture ; all the melts other than those used for investigation of the influence of small amounts of sodium, were subjected to an addition of sodium by the "double modification" process ; an electrically-heated muffle furnace was used for the heat-treatments ;

and heating for age-hardening was carried out in an oil bath with controlled temperature.

The influence of duration and temperature of heating before quenching for alloys containing Si, 12·5%, Mg, 0·25%, Mn, 0·45%, and Fe, 0·35% proved that the quenching temperature to be adopted for industrial practice may be fixed between 540 and 550° C., according to the precision of the temperature regulating device. The duration of heating may be fixed at six hours, the gain in properties resulting from prolongation of the treatment is very slight. Up to 135° C. the influence of age-hardening on the reduction of elongation is very slight.

Increase in silicon content was found to increase the tensile strength, the elastic limit and the hardness, but the fatigue strength appears to pass through a maximum between 9·5 and 11·5% silicon which may perhaps be due to the disappearance of the last primary crystals of silicon.

It is recommended that if castings are to be subjected to alternating stresses, it would be better to make them of an alloy having a silicon content in the region of 10% to be within the zone of maximum fatigue stress and, where castings are not to be subjected to severe alternating stresses, it would be preferable to use an alloy containing about 12·5% silicon, to ensure a combination of high elastic limit, tensile strength and hardness. The effect of magnesium is to increase the tensile strength, elastic limit and hardness and to diminish elongation by a large margin and the recommended maximum content is 0·25 to 0·03%.

The presence of sodium increases the elongation and, to a slight extent, that of tensile strength and hardness; and the influence of manganese in Al-Si alloys is to transform the brittle lamellar crystals of Al-Fe-Si into crystals of compact and less brittle form, and the manganese content to be adopted depends almost entirely upon the iron content. A content of 0·5% Mn is suggested, as allowing for the possibility of an addition of iron which may always occur in the course of manipulation of the alloy in the foundry, the iron content usually being less than 0·5% in practice.

Cobalt has an even greater transformation effect than manganese on the lamellar and brittle crystals of Al-Fe-Si. Making tests with an alloy containing Mg 0·25, Fe 0·35 and Co 0·45%, it was found that additions of between 7 and 11% of silicon resulted in little influence on the tensile strength or elongation, and the considerations involved tend to show that the silicon content adopted may be fixed at about 9%. Increasing additions of cobalt show that at about 0·4% Co the Al-Fe-Si crystals are transformed into more compact crystals, and at 0·6% Co, the crystals increase considerably in size and that the cobalt content should be kept at 0·45 to 0·5%, as it is likely that the large crystals resulting from higher content would prejudice fatigue strength.

There was found to be no appreciable difference between the influence of iron in alloys containing cobalt and that of the same metals in alloys containing an addition of manganese. Less sodium is required for alloys containing cobalt than for alloys containing manganese, when the surface of the metal has been protected during melting by 0·3% of salts.

It is shown that the heat treatable aluminium-silicon alloys represent a considerable advance over ordinary silicon alloys, having greater hardness, tensile strength and fatigue strength, and lower elongation.

Aluminium Casting Alloys

Various problems relating to foundry practice and metallurgy of aluminium casting alloys in Germany were discussed in a German Exchange Paper by Herr G. Gürtler and presented on behalf of the Technischer Hauptausschuss für Giessereiwesen, Düsseldorf. A study of the development of aluminium casting alloys in England and Germany reveals that in both countries, as elsewhere, three main types of alloy, of similar composition, are in use. These are the alloys with the principal additions of Cu, Si, or Mg, and that according to their required characteristics in service the alloys also contain further additions of a second of the three elements just mentioned and/or Zn, Ni, Fe, Mn, Ti, etc. For high-grade castings in this country, alloys on an Al-Cu basis with additions of Ni and Mg, such as the "Y" and "R.R." alloys are used, but in Germany greater importance has been placed on development of the Al-Si alloys which possess good casting properties and are age-hardened by addition of Mg.

The author considers the problem of removal of gases, particularly hydrogen, in detail, and considers that the most effective method is a combination of salt treatment (salts containing chlorine and fluorine) and allowing to stand, during which time the temperature need not be allowed to fall. The second and more difficult problem is to prevent the metal from re-absorbing gas while the mould is being filled, and this absorption of atomic hydrogen from the mould, generally green sand, can be reduced by lowering the pouring temperature, shortening the period of flow and increasing the rate of cooling.

The influence of Ti on the fatigue strength of Alpax alloy with various Si contents is discussed, and so also is the influence of various heat-treatments. In the case of this and certain other alloys, the increased solubility of Mg_2Si at high temperatures is utilised for improving the mechanical properties. In alloys containing several per cent. of Mg, the solubility of Mg_2Si is almost entirely prevented, while excess of Si has only a small influence on the solubility of the Mg_2Si. In the case of the Al-Si-Alloy, Alpax-Gamma, with an addition of 0·5% Mg, a considerable increase in tensile strength, yield point and hardness is secured by annealing at 530° C. and quenching in water, followed by heating for 20 hours at 150° C.

The same property is also possessed by the compound $MgZn_2$, contained in the artificially age-hardened alloys of the "G 54" group, distinguished by their suitability for anodic oxidation, the optimum alloys being those with a Mg + Zn ratio between 1 : 3 and 1 : 5·4 with which it is possible, after suitable heat-treatment, to attain tensile strengths of over 25 tons per sq. in., and hardnesses of over 140 kg./mm.², with only a slight elongation; the total content of Mg – Zn in this case being at 9%. This alloy is much in demand where good appearance and good mechanical properties are required.

Some Physical Factors in Casting High-Strength Brasses

The less important physical factors referred to by Dr. C. H. Desch in the third Edward Williams' lecture last June, have here been considered in relation to the casting of high-strength brasses by Mr. J. E. Newson, as these alloys illustrate these factors very well. In large castings the relative importance of these physical factors increases, and better facilities become available for their study. Although these alloys contain many desirable mechanical and physical properties, they present certain difficulties to those foundrymen who have had limited experience of them.

The mechanical properties of most alloys are influenced by the grain size, and the form and distribution of the constituents. Grain size is largely controlled by the thermal conditions existing from the time the molten metal enters the mould until the cold and solid casting is knocked out. There is not only the consideration of total quantity of heat for dissipation, but also of the rate at which it is, or should be, dissipated. The thermal conditions comprise those due to specific properties of the metal itself and which can only be varied by change of composition, including specific heat, latent heat of fusion, thermal conductivity, the temperature and extent of the freezing range; and those which can be varied under control by external means, such as the casting temperature, degree of superheat of the metal, and the nature and properties of the mould material.

The author discusses these factors for control, then

nalyses the individual factors under the headings of specific heat, latent heat of fusion, thermal conductivity, freezing range, casting temperature, mould material, and its thermal properties, the effect of fundamental physical factors, and has a few words on phase changes. He considers the thermal history of large castings, and gives experimental evidence.

The author makes no attempt to describe the methods adopted in laboratories to determine the values of the properties discussed, but it has been shown that these physical factors have a very real practical bearing on some of the problems encountered in non-ferrous foundries. The whole question of successful casting in all the commercial non-ferrous alloys is closely related to the thermal history and behaviour of the metal throughout the melting, casting, and cooling cycle, and such properties as specific heat and latent heat of fusion, varying widely from system to system, cover a much greater range than in the ferrous alloys. In some cases a high specific heat which may call for special measures in the foundry, may be one of the valued assets of the finished casting, as in the case of large aluminium alloy pistons for internal combustion engines, where high heat capacity without large temperature increase is needed.

Copper in Cast Iron

The results of experimental work carried out at the British Cast Iron Research Association on the influence of copper in cast iron are recorded in this paper by Mr. A. J. Nicol Smith. Incidentally, it contains an unusual volume of comprehensive, tabulated data of great value.

The conclusions drawn from the investigations of test-bars, consisting of Swedish white iron or hematite with relatively widely-spaced additions to a series of base irons covering a wide range of composition, were that the liquid solubility of copper in grey cast iron, under normal casting conditions, is about 5·5%, and beyond this percentage visible globules of primary copper are present. The solubility limits are little affected by rate of cooling or by composition, but the presence of nickel increases the solubility. When the quantity of copper is less than 3·5% in grey cast iron the copper behaves as though in solution, and is comparatively stable to heat-treatment.

The results also showed that in quantities up to 3·5% copper acts as a graphitising agent, being about one-third as powerful as silicon, but further copper beyond this figure reverses the effect, causing increase in chill, which is apparently due to dilution. No tendency to decompose the carbide of pearlite was noted.

It was established that the hardness of grey cast iron is increased by copper dissolving in the matrix. As copper acts as a graphitising agent it may simultaneously reduce the hardness by causing the decomposition of free cementite; in the absence of graphitising effect the hardness increase is about 10 to 11 points Brinell for each 1% of copper.

The fourth conclusion was that the influence of copper on the transverse strength though slight is favourable, but the influence on tensile strength is more favourable and more marked. Generally speaking, the mechanical properties reach their optimum values between 1 and 2% additions of copper. A further conclusion was that precipitation hardening of pearlitic grey cast iron gives no results of practical importance, and another was that copper has little influence on the microstructure of cast iron. It causes refinement of the pearlite and of the graphite; free cementite is decomposed, but no new constituent is introduced into the structure until free copper appears at 3·5%, and copper in excess of the liquid solubility limits is capable of giving rise to supercooled graphite. Grey cast iron is improved in regard to shrinkage by the addition of copper up to 1%, but 2% addition reduces this value to about the same as for base metal, and a 3% addition makes the material definitely worse for shrinkage.

Improved hardness and strength result from the combined addition of copper, together with one of the chilling elements—manganese, chromium, or molybdenum. A marked hardness increase results from the addition of copper and manganese; copper with chromium gives an all-round improvement, while the addition of copper plus molybdenum allows the latter to be added to an existing foundry mixture without influencing the chilling properties. The additions of copper plus manganese or of copper plus molybdenum are capable of giving a martensitic structure.

The Modern Manufacture of Machine-Tool Castings

This paper by Mr. J. Blakiston presents a survey of present-day practice and the developments taking place in the production of machinable grey-iron castings for machine tools. Numerous problems have been encountered; most machine-tool castings have to be machined internally and externally; exposed machined faces must be free from blemish, and those machined faces that are not exposed are often slide-ways which must also be free from any form of defect and be close-grained with good Brinell hardness value to resist wear.

The author considers the advantages, such as ease of casting to any desired shape—citing the present trend towards cellular construction with diagonal bracing,—and the cost of castings, stating that low production cost is evidenced by the fact that the cost of the castings, even when in alloy iron, is rarely more than 20% of the cost of the finished machine. He shows that cast iron possesses the necessary quality of rigidity and has good capacity for absorbing vibration. This raises an interesting point—namely, that the stronger the iron, the less is the apparent damping effect, which would indicate that certain castings for machine tools, such as legs, trays, and supports in compression, should be made from softer iron, on account of their greater damping effect.

The low coefficient of friction is another outstanding advantage adduced in favour of cast iron for this purpose. The three grades of cast iron commonly used in machine-tool construction are divided into (1) general engineering cast iron of straight pig and scrap mixture giving 1·0% phosphorus; (2) high-duty steel or refined iron mixture, medium phosphorus; and (3) low total carbon alloy cast iron. A brief description of the properties of these three grades is given, followed by notes on melting practice, the rotary melting furnace, rotary furnace linings, and a consideration of melting losses and gains. Moulding methods and refractory materials are also reviewed briefly; and the problems of fettling machine-tool castings made from high-duty and alloy metals are mentioned.

Sand-Blasting as Applied to the Vitreous Enamelling Process

The name sand-blasting is rather a misnomer these days, as sand is now very little used and the blast factor is more often crushed iron grit. The history and object of blasting are described by Mr. H. Whitaker. The three objects of blasting prior to vitreous enamelling are: to remove the hard skin which is of different nature from the rest of the metal and which does not enamel well; to remove all surface impurities such as sand, blacking and the oxide formed during annealing; and to roughen the surface to create a "bond" which enables the enamel to grip the metal.

Blasting has been proved best as the method for cleaning cast iron, for this purpose, and may also be applied to heavy gauge sheet steel. Lack of care on the part of the operator or the presence of oil or water in the compressed air has been found to be the basic reason for many enamelling troubles.

Five types of plant in common use: the room, the cabinet, rotary table, barrel, airless type, and their respective advantages and disadvantages are described very clearly. Operating troubles, the chief of which are water and oil in the compressed air supply, are dealt with and recommendations given.

Reviews of Current Literature

Electroplating

A Survey of Modern Practice

GREAT progress has been made in the spreading of scientific information on electro-deposition, and to-day modern practice is the result of the ready absorption of this information. The first edition of this book contributed to the development and became a standard work on the subject, presenting, as it did, solutions to numerous problems through the then exhaustive manner in which fundamental principles were discussed. With continued progress a second and enlarged edition became justified, and now the need for further amplification has necessitated a third edition.

In this new edition the authors have incorporated the results of a considerable amount of work which has been done during the past few years. Methods of control of both solutions and processes have become more defined, and analysis is now generally recognised as essential to uniformity of results; in this revision, therefore, the authors give a number of the more simpler estimations of essential constituents. The chemistry involved in this work is of fundamental importance to the electro-depositor, inasmuch as volumetric methods of analysis, which are so largely employed, are based on the equivalent quantities similar to those which govern quantitative electro-deposition. The broader knowledge of the chemistry of solutions is all to the good in an appreciation and solution of the problems arising in practice.

This book provides a fund of information for the electro-depositor; it includes data on nickel, zinc, cadmium and chromium-plating, as well as the metals usually associated with plating, and the deposition of alloys. It will continue to spread scientific knowledge of electro-deposition in the workshop.

By SAMUEL FIELD and A. DUDLEY WEILL. Published by Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London, W.C. 2. Price 12s. 6d. net.

The New Management

THIS is a very interesting book, full of sane reasoning on industrial administration; it is written in the light of the new spirit now manifest in industry; the spirit that has grown and sweetened the relations between all those engaged in industry to the general good; the spirit of friendship and willing co-operation between owners, management and workers, with the State holding a watching brief. This spirit is the result of a new outlook on management which is being slowly developed, a new outlook to meet modern conditions. With increasing competition in all trades, reduced profit margins from products of better quality and more intricate and difficult of manufacture, the old haphazard, fumbling, slow and wasteful managerial methods have given way to more scientific methods. The improved outlook of the workpeople, the higher standard of living, with shorter working hours and better conditions, have also contributed in compelling the adoption of these methods.

Since the beginning of this century industrial management has progressively armed itself to face its problems and perplexities, and although, in the early stages, economic and technical factors were stressed, frequently with a total disregard of the important psychological factor, a better understanding of the relative importance of these three factors has accomplished a change which is creditable to all who have striven to make industry meet their individual and collective needs.

The authors do not make the mistake of referring to the new management as "scientific" management, this term cannot rightly be used until psychology—the science of human reactions—has made such progress that human beings can be analysed and classified, and the laws that govern their actions and thoughts be accurately stated. Management is, above everything else, the art of handling, controlling and utilising to the full the abilities and efforts of human beings.

In a well-written introductory chapter, the authors state the modern manager recognises and distinguishes between three different aspects of every piece of work, and these may be termed the technical, the economic, and the psychological. In considering the technical aspect, one is concerned in deciding what result one desires to produce, how to produce it, and what equipment is best for the purpose. The economic aspect relates to the cost incurred, as to whether it is kept as low as possible, and the return obtained; and whether that return is sufficient to cover the cost, and thus enable the work to continue. Psychology deals with what has been called the human factor, which is perhaps the most difficult to guide and control perfectly, and yet the one that brings the richest success, in the quality, quantity, and cost of the result, and in other even more important ways.

The various scientific aids and systems which have been developed and are essential to success in modern management are admirably described and discussed, but it is recognised that the success with which they are applied will depend entirely on the quality of leadership shown by the supreme head, and communicated through him to his subordinates, immediate and remote. The authors deal with management as a whole and show how the parts are related to and react upon one another; thus an explanation of the fundamentals of economics is given at the beginning of the book and is followed by discussions on the work of organising, that on the latter being considered under two main headings: manufacture and commerce, and administration.

With regard to organisation, the authors conclude that rules, principles, systems, etc., can aid, can to an extent relieve, can supplement, and so be made to serve, but they can never be substitutes for the exercise of that justice and sympathy between man and man on which all success depends. The only control that is effective is self-control. The best manager or leader is the one who, appreciating this fact, so comforts himself towards his people as to bring out and develop their best qualities and the highest traits in their characters.

The chapter on work and time studies is very informative and should be read carefully by principals, managers and potential managers in all industries. It is in this direction that there is room for considerable improvement in this country. Obviously an immense increase in production and national wealth is necessary before we can be in a position to raise the standard of our people to a level with which we can be satisfied. This can only be done by the examination of work in detail in some form of time and motion study. The method of carrying out such studies is explained in this book by means of illustrations taken from practice, but it is emphasised that the willing and whole-hearted co-operation of the worker should be obtained, both in the course of the study and afterwards in putting into force the changed practice.

The first part of this book also deals with some important features in modern production, particularly the interchangeability of parts, flow of work, and standardisation, and the effect of these features on the workmen; standardisation and inspection, which should be an organising and testing activity influencing all departments, offices and workshops of an undertaking; the elements of accountancy, which are treated under several divisions; and concludes with a discussion of the technique of investigating and reorganising an existing concern.

The second part is concerned with the application of the principles given in the first part and gives examples drawn from the actual experience of the authors. The examples chosen are applicable to industry generally and make clear the methods of investigation recommended. This part contains a work and time study for improving equipment and practice in a rolling mill; presented under five headings: the time study, rationalisation, the wages

problem, the costing system, and proof of economy, this is a very informative example. Other examples include: work and time study in a jobbing forge; determination of performance times in cylindrical grinding to limits; determination of working time in a Steckel mill; chipping of steel billets; rough turning of round billets; industrial psychology in a cigarette factory; and re-organisation of equipment for steel-making.

In the third and concluding part the authors extend application of the principles to industries and to other activities. They refer to two classes of industries: the newer ones, as, for instance, the automobile and electrical industries, and the older ones, such as coal, iron and steel, shipbuilding, house-building, etc.; more attention, however, is given to the latter class.

This is an outstanding book on the art of management with the various scientific aids and systems now available admirably discussed. We know of no book to compare with it, the subject is presented in a lucid form which is not only informative but interesting. While the authors have kept close to actual practice, they do not pretend to provide " cut and tried " methods, but to guide principals, managers and potential managers in all industries, to a better understanding of the fundamentals of good management, and they are to be congratulated on producing a really thought-provoking book on the subject which should fulfil its object.

By H. T. Hildage, T. G. Marple and F. L. Meyenburg. Demy 8vo, 358 pages. Published by Messrs. MacDonald and Evans, 8, John Street, Bedford Row, W.C. 1. Price 16s. net.

Metal Aeroplane Structures

This is a most comprehensive treatise on the design and construction of the major components of a large number of representative aircraft, forming a practical and authoritative work in which are discussed the underlying principles of design, materials of construction, structural elements, dealing with welded and riveted joints, stressed-skin design, metal wings and beams, fuselage, also hull and float design.

The permissible loads that various types of structure will withstand, and the stresses developed through the various loadings, are fully treated in the text; and, as monocoque fuselage construction and thin web design are used so extensively by most American manufacturers, these are considered in full detail.

The author states that laboratory research, design and manufacture of metal airplanes, have reached a stage where a record should be made of their technical developments, for the benefit of those who are students of aeronautics, and the designers and engineers whose job it is to create the commercial and military ships-of-the-air for the travellersand fighters of to-morrow. That this consideration is fulfilled is quickly evident, and the book deals in turn with the following phases of the subject: types of metal airplanes; materials of construction; structural elements; welded joints; riveted joints; stressed, skin design; types of metal wings; metal wing beams; wing design; fuselage design; and hull and float design. The factors of combined bending, compression and torsion in tubes; composite sections, extruded structural shapes and rolled structural shapes are considered; principles and tests of many types of stressed-skin construction and various materials are included, and metallurgists and engineers will find much of interest in regard to the factors of design and tests for metal wings, beams and fuselages.

Stressed skin design makes use of the outer cover of an airplane body to carry stresses which would otherwise demand additional structural material. Tensile stresses can be carried easily if there is proper continuity at the splices and shear can be carried if the sheet is moderately thick, or by the formation of diagonal tension field such as a Wagner beam for internal structure. Sheet used in aircraft work is not as a rule thick enough to carry compression stresses, but it is possible to design the component with internal stiffeners to carry the compressive load and use the skin to reinforce and support the stiffeners so that they can accommodate greater stresses.

English practice in wing design is exemplified by the Monospar and the Blackburn-Duncanson single spar types —the latter being a thin walled tube of circular section placed at the maximum thickness of the wing and tapering towards the wing tips; this being the only main structural member. The construction of this spar comprises the sheet metal shell attached to light internal diaphragms and reinforced along its top and bottom surfaces by strips of corrugated metal. The Dewoitine single spar—consisting of two duralumin flanges and two openwork sheet webs—the two-spar Curtiss, Hall, and Loire wings are instanced as examples of two-spar design in modern wings.

It is interesting to note that many American designs use aluminium alloy components, as contrasted with the steel strip construction for rib assemblies used by the Gloster Aircraft Co. Ltd. in this country, taking this as one example. The author states that " Duralumin is the preferred material for metal wing beams in the U.S.A., but in Great Britain steel is used almost exclusively, the steel wing beams being of relatively shallow depth and made from strip steel. This has been made possible through the use of high tensile, chromium-nickel stainless steel, and the development of suitable fabricating machinery."

Instances are given of beam sections used by the Bristol Co., by Boulton and Paul Ltd., Armstrong-Whitworth, Gloster, Hawker, and Vickers.

Tests carried out with a Boeing rib of welded steel tubular construction, designed for an airplane weighing 8 tons, with a wing of 11 ft. chord, showed that with the smallest practical sizes for the members it was much too strong and too heavy to be suitable for an airplane of that size; and that a Boeing rib of duralumin, composed of square section flange channels with riveted gusset type plates, had the highest load-weight ratio but also was too strong and heavy for the same type of airplane. In the cantilever wing of the Boeing Transport the air loads are taken by the smooth duralumin skin and transmitted to channel type stringers, thence to the ribs and from the ribs to the spars. Duralumin channels, square and round tubes, with riveted gusset type joints are used throughout the structure. All bending stresses are taken by the spars, the skin being used to resist shear and torsion.

The question of vibration tests is not mentioned in any detail but there is interesting reference to this subject in connection with the single-spar Dewoitine wing previously mentioned. This cantilever wing has an aspect ratio of 10 and one of the greatest difficulties involved in the design of a wing with this aspect ratio is the elimination of vibration. But it is stated that the wing of the Dewoitine 33 does not vibrate at any engine speed or angle of attack. The stiffness of the wing is further shown by the fact that if the ailerons are suddenly deflected at full throttle in horizontal flight no torsion of the wingtips is observ d. The design features of this type of wing are given in detail.

This book is illustrated with nearly 300 drawings, photographs and charts, including 68 useful tables. Every chapter contains useful formulæ, and the whole of this comprehensive matter is presented and described in a commendably clear style. Reference is made to design and constructional features of a representative group of American, English, French and German machines; we note, however, that that most interesting development—geodetic construction—is not mentioned. There may be, of course, a good reason for this omission. The book will be of special value to engineers and all interested in the fabrication and application of light metals, and forms the most complete work on this subject that we have yet received.

By Major Flavius E. Loudy, B.S.E. (Ae.E.). Published by Constable and Co. Ltd., 10, Orange Street, London, W.C. 2. Price 24s. net.

Drying Gases with Activated Alumina

ACTIVATED alumina is an important new adsorbent which is now being employed successfully in a number of commercial drying processes, according to Derr. It is a granular, inert, porous solid, capable of removing practically 100% of the moisture from air or gases passing through it until it is taken up to about 12 to 14% of its weight of water. After use, the material is reactivated by passing air through the column of adsorbent in reverse direction to that employed for passing the gases to be dried. Under the best conditions it is possible to reduce the moisture content of a gas to less than 0·0008 mg/litre.

The amount of moisture removed will depend on the depth of the activated alumina through which the gas is passed, the temperature and the rate of flow. For complete removal of moisture a height of adsorbent equal to 3 to 4 times the diameter of the layer is suitable. For drying large volumes of gas layers of alumina 4 to 10 ft. deep and having a height suitably selected on the basis of having a reasonable resistance to flow are used. In the adsorption of 1 lb. of moisture from any gas an amount of heat approximately equal to that evolved during the condensation of 1 lb. of steam is liberated. This heat is stored up by the alumina in the region in which adsorption at high efficiency takes place and no rise in temperature of the exit gases takes place. The temperature of the exit gases will start rising after a time equal to about half the adsorption period ; but adsorption at high efficiency will continue until the exit gas approaches a certain maximum temperature, after which the efficiency of adsorption will gradually decrease. By suitably removing the heat generated during the adsorption of the moisture, the length of time, during which maximum efficiency of adsorption is maintained, can be prolonged.

Increasing the rate of flow of the gas through the adsorbent tends to decrease the capacity at high adsorptive efficiency. Flow rates between 10 and 20 cubic ft. per hour per lb. of activated alumina are suitable for complete drying. For the purpose of regenerating the alumina air-heated to 450-475° is passed through it. The process of reactivation adsorbs heat and completion of reactivation is shown by the rapid increase in temperature of the exit gas. Industrial applications of activated alumina for drying purposes may be divided into two classes, the first in which as complete a drying of the gases as possible is required, and the other in which only partial removal of the moisture from large volumes of gas is necessary. With the former, when using activated alumina for drying gases under high pressures, attention is necessary so that these pressures do not approximate to the critical pressure of the particular gas being dried, as otherwise considerable adsorption will take place.

Drying equipment used for the partial drying of gases differs in design from that used for the complete drying. In general, beds 2 to 3 lb. deep and air velocities of 75 to 150 ft. per minute are employed, this being equivalent to about 300 to 1,000 cu. ft. per hour per lb. of alumina. As these high rates of flow reduce the time of contact between the gas and the alumina the practical capacity of the adsorbent is reduced to between 3 to 5% of the weight of the alumina before adsorption cycle. Partial drying is particularly well suited for maintaining lower than normal humidities in industrial plants, where hygroscopic chemicals, candy, pharmaceuticals and other products sensitive to moisture are being dried, packaged, fabricated or stored. An example of such an application referred to is the use of dried atmospheres for the purpose of preventing condensation of moisture on painted surfaces cooled by the rapid evaporation of the paint solvent.

Another activated alumina installation is used in conjunction with the drying of celluloid products where the dried air prevents blemishes which form on the product when the moisture concentration becomes too great.

New Type Single Roll Coal Breaker

EDGAR Allen and Co., Ltd., have put on the market a 15 in. × 15 in. size of Stag single roll coal breaker for use on colliery screening plants to crush middlings or inter-stratified coal. This machine has a number of important constructional points and advantages. It can be successfully used on ash, clinker, salt, bones, alum, etc., and, in fact, any other friable materials. It is particularly economical for small outputs, has low operating and maintenance costs and a compact design. The crushing roll is built up of segments made from Imperial cast manganese steel mounted on to a cast steel drum. This can be easily removed and renewed. Special attention has been paid to the breaker plate so that the tendency of the material to choke is eliminated and breaking is carried out in an entirely scientific manner. A special feature is the safety device. The machine has a capacity of 10 to 15 tons per hour with a feed size of up to 8 in. cube, reducing to approximately 1¼ in. to 2 in. cubes. A suitable design for portable plants can be supplied.

Measurement of the Thickness of Tin on Tinplate

Two new instruments have been devised for measuring the thickness of tin coating on tinplate. Previous methods of estimation were chemical and suffered from the disadvantage that a considerable time was required, and as the coating had to be removed the tinplate was spoiled. One of the new instruments is magnetic, and the other electro-magnetic. They are both capable of giving results rapidly without detriment to the tin coating.

The method of Chalmers and Hoare employs a cobalt chrome-steel permanent magnet, and measures the force necessary to pull it off the sheet using a syphon-operated water balance for this purpose. The second instrument, devised by Tait, uses a small transformer which is placed upon the sheet so that the magnetic circuit is the core of the exploring head, the gaps formed by the non-magnetic coating and the basis material. The former is particularly useful for plotting the contour of the surface, and the latter is primarily a workshop instrument for measuring the average thickness and large-scale variations. Differences of thickness in the coating of five-millionths of an inch can be measured by the magnetic method.

This publication may be obtained free of charge from the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C. 2.

Business Notes and News

New Steel Tube Plant at Chesterfield

The Chesterfield Tube Co., Ltd., have recently completed the erection of new shops, which are being equipped for the production of very large tubes. The new plant will enable the manufacture of pierced and drawn weldless steel hollow cylinders of a size and weight previously unobtainable by this process. The manufacturing range will comprise standard weldless steel products up to 40 in. diameter, with a maximum length of 35 ft., while special products will be made up to 52 in. diameter. Ingots up to a weight of 16 tons will be used, giving a finished product up to about 12 tons in weight.

Furnace Control Equipment

Messrs. Ferranti, Ltd., have entered into arrangements with Messrs. Wild-Barfield Electric Furnaces, Ltd., and their associated company, Messrs. G. W. B. Electric Furnaces, Ltd., whereby these two companies have the sole right for the supply of Ferranti moving-coil voltage regulators when fitted with the Ferranti temperature voltage relay control for furnace work.

The combination of these equipments enables extremely close control of temperatures to be maintained, due to the fact that the electrical input to the furnace is automatically adjusted to suit the demand. Thus, with the furnace idle or maintaining a charge at any desired temperature for a prolonged soaking period, the input is reduced to a figure which balances the radiation losses and so gives a perfectly steady temperature. On the other hand, when a new charge is put into the furnace the input is automatically increased at first, and then gradually reduced according to the "receptivity" of the charge to absorb heat.

Whilst for many processes the well-known usual forms of automatic temperature control are satisfactory, for treatments where minimum temperature fluctuations are essential this moving coil regulator, with automatic adjustment, offers advantages difficult, if possible, to obtain by other means.

Reduction in Copper Prices

The main reason given for the fall of more than £3 in the price of copper during the last week of May was the reduction in the U.S. domestic price. This proved to be the lowest level for copper for two years or so, but the U.S. domestic price reduction was not the only reason.

This U.S. reduction was not unexpected as the U.S. position was known to be becoming gradually worse, but we must consider the fact that the trade demand from Europe, stimulated by heavy Russian buying in the earlier part of the year, has now declined. Whether this indicates reduction in consumption is not apparent, however. Producers have shown increased willingness to sell, and American exports of domestic copper continue at the rate of more than 10,000 short tons monthly.

It seems possible that large U.S. stocks and lack of American consumer buying in volume is having an adverse effect on the export agreement. Possibly, too, these U.S. exports may represent actual sales to consumers, and not be an indication of transference of stocks from America to other parts of the world. Naturally enough, whilst the export price is above the domestic price, then exports will be encouraged and the relationship between these American export and domestic figures will materially affect the London market. Present circumstances make it difficult for the London market to rise above the upper limit set by the U.S. domestic price.

If the recent reduction in demand is a fair indication of lower consumption, then it is possible that producers may cut the quota, but a 5% cut should not have any marked or immediate effect on the price; a contention that is borne out by previous experience.

Copper is mainly used by the capital equipment industries and their activity is not governed by the price of copper, and no substantial revival can be anticipated in the American market for some time so that the drop in price in the U.S. home market does not appear to be justified, although it may prove to be a fugitive stimulus.

Another possibility is that the American domestic price may be stabilised for a time at 9·00 c., which should result in comparative stability in the London market at, or a little above, its current level. As the Institute figures showing the apparent American consumption may not be published, the future position can only be estimated.

Yeovil Engineering Firm's New Activity

Petters, Ltd., the Yeovil Diesel-engine makers, have completed arrangements for launching an important new type of light air-cooled general utility engine, which is being manufactured on mass-production lines. Production of the new engine, which is being made in 1½-h.p., 2-h.p. and 3-h.p. units, has already begun, and a large department of the Yeovil works has been organised to accommodate the new activity.

The new engine, which can be driven equally well by petrol or paraffin, is designed for use on farms, for small electric lighting sets, road-making machinery, pumping plants, hoists and general utility purposes. It is being manufactured on the conveyer-belt system, which makes possible a very large output, and the Company's programme provides for production at the rate of many thousands a year.

Naval Expansion

A supplementary Navy Estimate for £2,410,500 was recently issued. This includes £1,773,500 on account of the new construction programme, £264,200 marriage allowance for Royal Naval and Royal Marine officers, £730,800 for increased marriage allowance to Naval ratings and increased pay to special service ratings, and payment of £92,000 as the first instalment on the purchase price of a seaplane carrier which is to be acquired from the Government of Australia, and the receipt of the first instalment of the price of a cruiser which is to be transferred to that Government on repayment, the instalment being £450,000.

The new ships to be ordered in 1938 are two battleships, seven cruisers, one aircraft carrier, the seaplane carrier to be purchased from Australia, two submarines, a destroyer depot ship, a submarine depot ship, a fleet air arm supply and repair ship, three minelayers, two gunboats, seven motor torpedo boats, three general service lighters, a baggage lighter and a number of smaller vessels.

Mechanised Foundry at Dursley

The new foundry building, which Messrs. R. A. Lister and Co. have erected and equipped at their Dursley (Gloucester) works, is 360 ft. long and 170 ft. wide, designed for an ultimate throughput of 130 tons of molten metal in an 8-hour day. Lighting has been well considered, and artificial lighting, when required, will be supplied by a system of mercury-vapour lamps.

This modern equipment includes comprehensive treatment for recovery and reconditioning of the sand. The use of synthetic clay is standard practice—a clay-free silver sand being mixed with a colloidal clay. There are approximately 75 tons of sand in the system, and the installation caters for cooling, extraction of foreign matter, humidification, aeration, and the addition of fresh material.

The basis of this mechanised foundry system is a 200-ft. long platform conveyer passing along the centre of the building. Transmission is by moving chain, and the cast-iron plates of 3 ft. 3 in. by 3 ft. travel at speeds varying up to a maximum of 12 ft. per minute. At one end are two balanced-blast 6-ton per hour cupolas which operate on alternate days. From these cupolas the molten metal is carried in ladles by mono-rail to a pouring platform adjacent to the central conveyer. The moulding boxes pass slowly along the conveyer, then, after pouring, travel through a hood that is 155 ft. long, through which air is drawn. The knock-out is at the other end of the conveyer, and the final emptying of the steel moulding boxes is done by hand over a grating.

The castings are then sent to the cleaning and fettling departments in containers, and the boxes themselves returned to the moulding department by another conveyer. Boxes for the larger castings, too heavy to be lifted manually, are handled by pneumatic crane.

This new foundry has been planned for the production of high-grade castings at lowest possible cost, and for eliminating much of the hard manual labour associated with foundry production in conditions of maximum light and clean air.

Personal

F. W. Haywood, Ph.D., B.Sc., A.I.C., has been appointed chief metallurgist to Messrs. Wild-Barfield Electric Furnaces Ltd., to take charge of the new research department now nearing completion. Dr. Haywood, who is at present engaged with Messrs. I.C.I. (Fertiliser and Synthetic Products) Ltd., at Billingham, will commence his new duties later in the year.

MARKET PRICES

ALUMINIUM.

98/99% Purity	£100	0	0

ANTIMONY.

English	£76	0	0
Chinese	56	0	0
Crude	32	10	0

BRASS.

Solid Drawn Tubes	lb.	0	0	10¾
Brazed Tubes	,,	0	1	0¾
Rods Drawn	,,	0	0	8½
Wire	,,	0	0	7¾
*Extruded Brass Bars	,,	0	0	4⅝

COPPER.

Standard Cash		£34	2	6
Electrolytic		38	10	0
Best Selected		38	5	0
Tough		38	0	0
Sheets		70	0	0
Wire Bars		39	10	0
Ingot Bars		39	10	0
Solid Drawn Tubes	lb.	0	0	11¾
Brazed Tubes	,,	0	0	11¾

FERRO ALLOYS.

‡Tungsten Metal ° Powder, nominal	lb.	£0	4	9½
‡Ferro Tungsten ° nominal	,,	0	4	8
Ferro Molybdenum °				
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL				
2–4% Carbon, scale 12/- per unit	ton	34	15	0
4–6% Carbon, scale 8/- per unit	,,	24	5	0
6–8% Carbon, scale 7/6 per unit	,,	24	0	0
8–10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon. scale 13/- per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/- per unit	,,	12	10	0
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	18	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	0	0
Scotland	—	2	0	0
Durham	—	1	14	6
Furnace Coke—				
Scotland		1	15	0
S. Wales	—	1	12	6
Durham	—	1	10	0

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£59	0	0
*Commercial Ingots		44	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—			
Crown Bars	£13	10	0
N.E. Coast—			
Rivets	12	15	0
Best Bars	15	15	0
Common Bars	12	10	0
Lancashire—			
Crown Bars	13	10	0
Hoops	14	2	6
Midlands—			
Crown Bars	13	10	0
Marked Bars	15	15	0
Unmarked Bars		—	
Nut and Bolt Bars	11	15	0
Gas Strip	14	2	6
S. Yorks.—			
Best Bars	15	15	0
Hoops	14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	10¼
†Sheet to 10 W.G.	,,	0	0	11
†Wire	,,	0	1	0½
†Rods	,,	0	1	0
†Tubes	,,	0	1	6¼
†Castings	,,	0	1	3

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£6	13	0
Foundry No. 1	6	0	6
,, No. 3	5	18	0
N.E. Coast—			
Hæmatite No. 1	6	13	0
Foundry No. 1	5	11	6
,, No. 3	5	9	0
,, No. 4	5	8	0
Silicon Iron		—	
Forge	5	8	0
Midlands—			
N. Staffs. Forge No. 4	5	8	0
,, Foundry No. 3	5	11	0
Northants—			
Foundry No. 1	5	11	6
Forge No. 4	5	5	6
Foundry No. 3	5	8	6
Derbyshire Forge	5	10	0
,, Foundry No. 1	5	14	0
,, Foundry No. 3	5	11	0
West Coast Hæmatite	7	4	8
East ,, ,,	7	3	6

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.	
Per English ton	Kr.195
Billets, single welded, over 0·45 Carbon.	
Per metric ton	Kr.335-385
Per English ton	£17 11 3/£20 3 9
Wire Rods, over 0·45 Carbon.	
Per metric ton	Kr.375-405
Per English ton	£19 12 2/£21 4 9
Rolled Martin Iron, basis price.	
Per metric ton	Kr.230-250
Per English ton	£12 1 2/£13 2 2
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.360
Per English ton	£18 17 6

f.o.b. Gothenburg.

SCRAP METAL.

Copper, Clean	£32	0	0
,, Braziery	29	0	0
,, Wire		—	
Brass	22	10	0
Gun Metal	32	0	0
Zinc	8	0	0
Aluminium Cuttings	71	0	0
Lead	13	10	0
Heavy Steel—			
S. Wales	3	10	0
Scotland	3	6	0
Cleveland	3	7	0
Cast Iron—			
Midlands	3	5	0
S. Wales	3	10	0
Cleveland	4	2	6
Steel Turnings—			
Cleveland	2	12	6
Midlands	2	5	0
Cast Iron Borings—			
Cleveland		—	
Scotland	2	2	6

SPELTER.

G.O.B. Official		—	
Hard	£9	15	0
English	13	12	6
India	12	10	0
Re-melted	10	5	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£11	10	0
North-East Coast	11	10	0
Midlands	11	10	0
Boiler Plates (Land) Scotland	12	0	0
,, ,, (Marine) ,,		—	
,, ,, (Land), N.E.Coast	12	0	0
,, ,, (Marine) ,,		—	
Angles, Scotland	11	0	6
,, North-East Coast	11	0	6
,, Midlands	11	0	6
Joists	11	6	0
Heavy Rails	10	2	6
Fishplates	14	2	6
Light Rails	10	7	6
Sheffield—			
Siemens Acid Billets	11	15	0
Hard Basic .. £6 17 6 to	10	2	6
Medium Basic, £6 12 6 and	10	0	0
Soft Basic	8	15	0
Hoops	11	15	0
Manchester			
Hoops	11	5	0
Scotland, Sheets 24 B.G.	15	15	0

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Finished Bars 14% Tungsten	lb.	£0	3	0
Finished Bars 18% Tungsten	,,	0	3	10
Extras :				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to $\frac{3}{16}$ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ⅜ in.	,,	0	0	3
,, ,, ½ in. × ¼ in.	,,	0	1	0

TIN.

Standard Cash	£169	15	0
English	169	15	0
Australian		—	
Eastern	172	0	0
Tin Plates I.C. 20 × 14 box	1	0	3

ZINC.

English Sheets	£27	10	0
Rods	18	10	0
Battery Plates		—	
Boiler Plates		—	

LEAD.

Soft Foreign	£13	2	6
English	15	5	0

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Victor X-Ray Corporation Ltd., London and Chicago.

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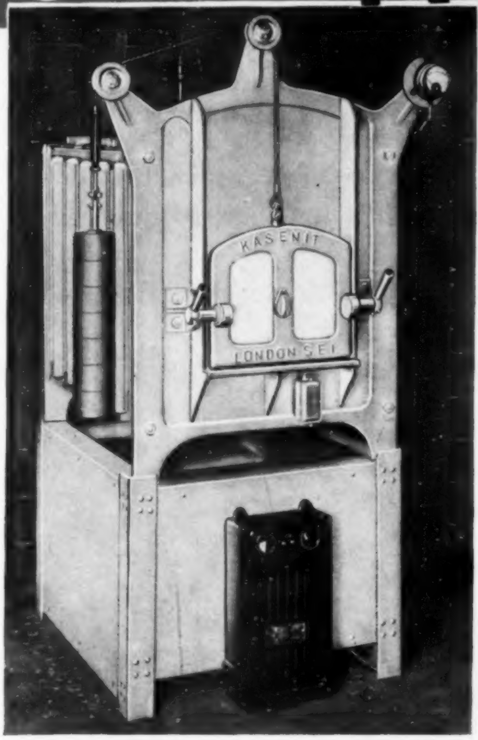
New KASENIT Furnace



WITH IDEAL ELEMENT PROTECTION INTEGRAL WITH THE HEARTH . . .

The elements are freely supported in the channels of the chamber and are free to expand and contract without mechanical strain—the refractory chamber is of substantial thickness and is mechanically strong—the elements have long life and are quickly and easily replaceable when necessary without dismantling the Furnace. Cost of replacement is low.

Economy and reliability is made possible by the location of the elements close to the inside of the refractory chamber with free heat circulation, so that high temperatures can be obtained without over-running the element.

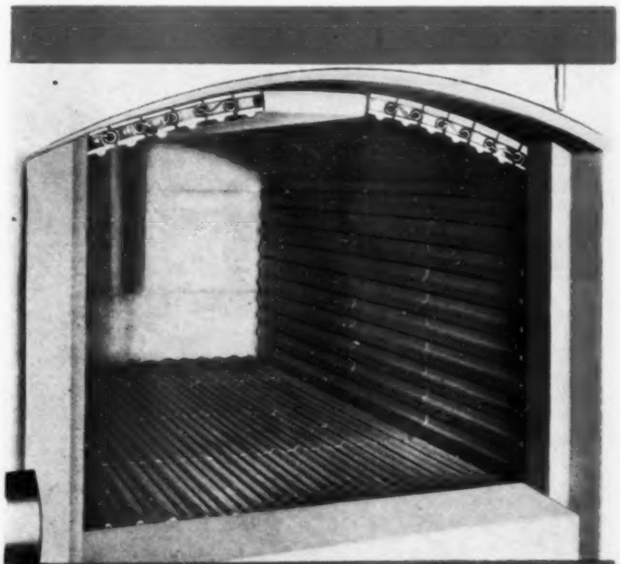
The refractory chamber is built up of large section refractory bars interlocked to allow for expansion and contraction. The elements are carried in channels running from back to front and are connected to bus bars at the back of the Furnace.

- These Furnaces can be supplied with three-heat switches or self-contained temperature regulators. With the Impulse Type Regulator, the range of temperature variation is between 200° and 1,000° C., or to the full temperature for which the Furnace is designed.

- Furnaces can be designed with heavier loading to reduce heating-up time and for heavy duty.

  Automatic temperature controllers can be used without any further contactor gear, and on single or three-phase.

- The Impulse controller automatically regulates the supply of energy to the elements, on a time basis, switching on and off for equal and specified periods, so that if the maximum loading of the Furnace was 10 Kw. for one hour, the energy used would be 5 Kw., or 5 units per hour.



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